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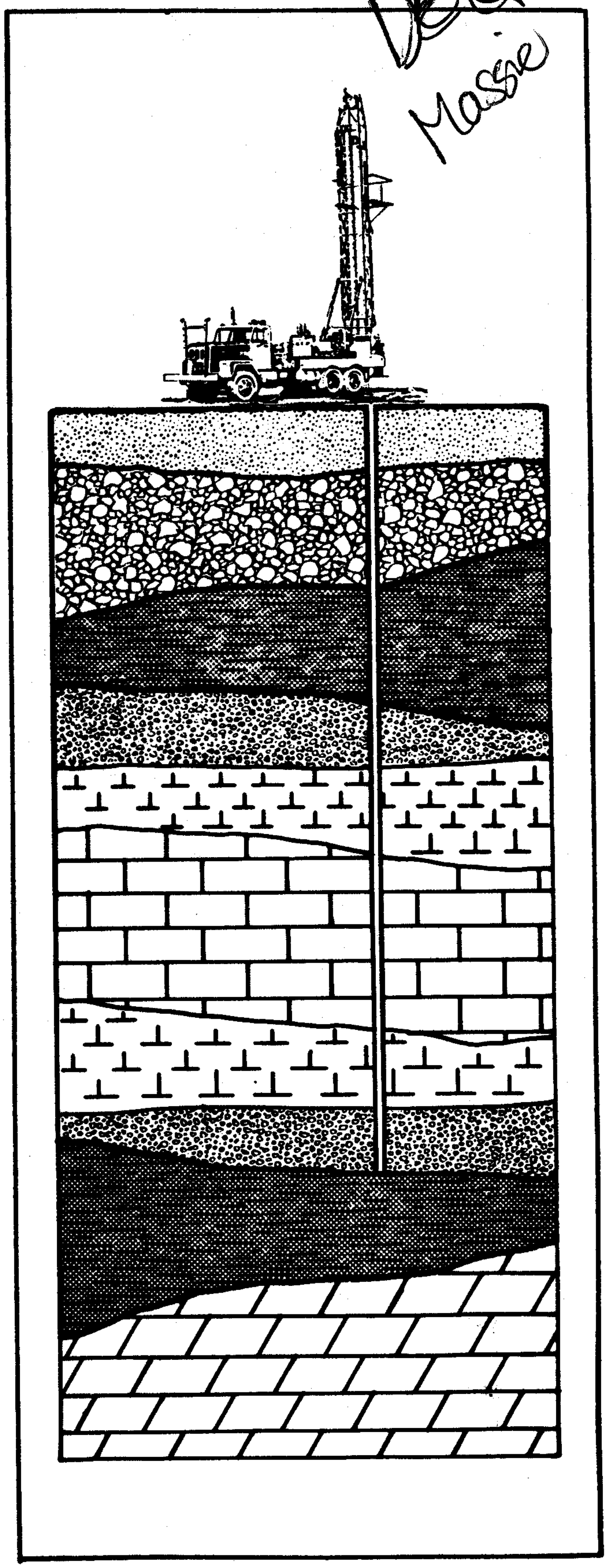

GROUND WATER RESOURCES OF THE EASTERN SHORE OF VIRGINIA

By
Robert J. Fennema
and
Virginia P. Newton

TIDEWATER REGIONAL OFFICE

COMMONWEALTH OF VIRGINIA

STATE WATER CONTROL BOARD

Richmond, Virginia

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ACKNOWLEDGEMENTS

This report was made possible through a grant from the Coastal Plains Regional Commission and additional funding by the Water Resources Commission. The assistance of the Soil Conservation Service in locating suitable research station sites was invaluable and their efforts in obtaining additional funding is greatly appreciated. The public-spirited property owners, on whose land we were allowed to drill and monitor, deserve special commendation. The Town of Chincoteague, Exmore Foods, Inc. and Kane Miller Corporation, whose help and cooperation made the aquifer tests possible, is gratefully acknowledged. Many thanks are extended to the drillers of Delmarva and Creason Well Drilling companies for their efforts in the drilling of the research stations, and to Jimmy Bundick of Bundick Well and Pump who generously shared his well drilling files with us.

Most importantly the authors wish to express our appreciation to Sherry C. Hunt who diligently typed the many revisions to this manuscript, and to R. A. Masiello, Division Director, and L. S. McBride, Regional Director, who read and offered helpful criticisms of the manuscript.

SUMMARY

Fifteen ground water research stations have been drilled to obtain geologic and hydrologic data of the aquifer underlying the Eastern Shore of Virginia. A ground water monitoring network was established to provide long term hydrologic data. Aquifer tests were conducted on three of the major well fields. Aquifer coefficients calculated from these tests were used to develop distance-drawdown graphs employed in evaluating existing conditions. Additionally these graphs, coupled with the hydrogeologic and water quality information, can be used for planning additional ground water withdrawals.

The hydrogeology of sections of the Eastern Shore are discussed and examples of current hydrologic conditions are presented. Outside current cones of depression ground water potential is thought to be twice current usage, but proper management of the resource is needed to prevent salt water intrusion and to minimize well interference problems.

Although several large cones of depression have formed in both Accomack and Northampton Counties, no occurrence of salt/fresh water intrusion or over pumping was found. Continual monitoring of water quality and water levels will provide a better record of long term effects of current pumping and provide better estimates of potential for additional withdrawals.

GRANTS

This report is the result of a study supported by a grant from the Coastal Plains Regional Commission under Agreement Number 1074007. The grant provided for the drilling of ground water research stations, the gathering of relevant hydrologic data and the development of a computer model used in the evaluation of the water levels and water quality of the Eastern Shore. Additional funding was provided by the Water Resources Council and the Coastal Plains Regional Commission to extend the project for one year to October 1981 and perform several pump tests so that quantity data could be developed.

The computer model was completed in October, 1977 and published by the State Water Control Board as Planning Bulletin 309. The data gathering and drilling of the research stations started in April, 1977 and has continued until February, 1981. Three aquifer tests were performed and evaluated from October 1980 to October 1981. Monitoring of water quality and water levels at the research stations continued during the year extension and will continue to be part of the State Water Control Board's data gathering programs.

METHODS OF INVESTIGATION

The largest portion of the field work carried out under this program consisted of the installation and monitoring of fifteen research stations. These stations, consisting of from three to four observation wells, were drilled on private property leased from the owner through a long term contractual agreement. The research station sites were determined and surveyed with cooperation from the field office of the Soil and Conservation Service located in the Town of Accomac. Drilling of the stations was contracted to private drillers using a closed bidding system. Of the fifteen stations, twelve were drilled by Delmarva Drilling Company from Bridgeville, Delaware and two were drilled by Creason and Sons from Zuni, Virginia. One station was installed as part of the regular State Water Control Board's drilling program.

In addition to the research stations, an effort was made to obtain geohydrologic data from existing wells on the Eastern Shore. This data collection effort consisted of obtaining geophysical logs and geologic logs from all newly drilled wells on the Eastern Shore and establishing a water level monitoring network using both the research stations and existing commercial and industrial wells. These same wells were also used to obtain quality data. As this sampling network is monitored in the future, long term records can be established which will give a reliable indication of water quality trends in the ground water supply of the Eastern Shore.

PREVIOUS INVESTIGATION

Several reports dealing with the ground water conditions on the Eastern Shore have been published. The earliest report dealing specifically with Accomack and Northampton Counties is by Samuel Sanford titled The Underground Water Resources of the Coastal Plain Province of Virginia, Bulletin No. V, 1973 of the Virginia Geologic Survey. A more recent report by Allen Sinnott and G. Chase Tibbitts, Jr., was published in 1968 and titled The Ground Water Resources of Accomack and Northampton Counties, Virginia, Mineral Resources Report 9, prepared by the Virginia Division of Mineral Resources. A third report was published by the State Water Control Board as Planning Bulletin 45, Groundwater Conditions in the Eastern Shore of Virginia, 1975, by E. A. Siudyla.

GENERAL

Accomack and Northampton Counties comprise the study area and are collectively referred to as the Eastern Shore of Virginia (Figure 1). They make up the southern portion of the Delmarva peninsula which includes the eastern portion of Maryland and all of Delaware. The peninsula is bordered to the west by the Chesapeake Bay and to the east by the Atlantic Ocean. It is connected with the Virginia mainland by the Chesapeake Bay Bridge Tunnel.

The Eastern Shore is physiographically a part of the Coastal Plain Province, a seaward sloping stratified body of sediments, bounded on the west by the Fall Line and on the east by the Atlantic Ocean. The sediments in the two counties consist primarily of unconsolidated gravel, sand, silt and clay. The peninsula trends in a north-south direction and is about 70 miles long. It is relatively narrow with an average width of eight miles in Accomack and six miles in Northampton County. Coastal islands and extensive tracts of marshes separate the mainland from the Atlantic Ocean. Marshes are also found on the western side, Chesapeake Bay, especially along the Accomack County shore line. However, erosion has eliminated most of the marshes along the coast line in Northampton County. The topography is predominately level and has a maximum surface elevation of 50 feet. The present surface features consist of Pleistocene Terraces; individual units can be distinguished by different soil types and changes in elevations. Two distinguishable elevation changes occur at the bay and ocean side. The land in between is referred to as the upland and along the shore as foreland.

The central portion of the Eastern Shore is relatively flat but does form the drainage divide. The Eastern Shore is well drained and is characterized by several creeks which in their lower reaches are tidal estuaries fed by narrow branches. These estuaries are more pronounced on the Chesapeake Bay side and receive most of the surface and ground water drainage. In contrast, the creeks are smaller and less pronounced on the ocean side.

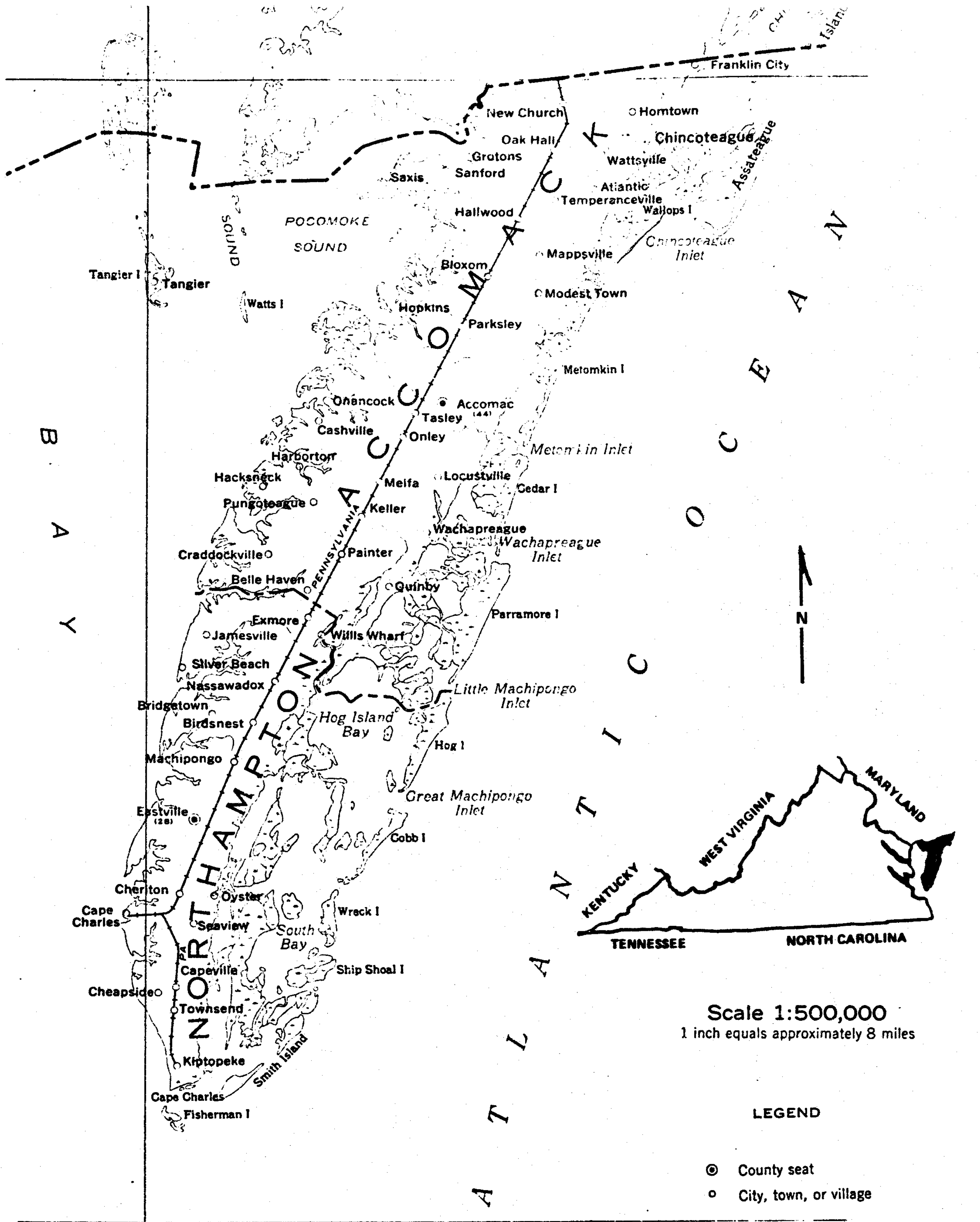


FIGURE 1. LOCATION MAP OF THE EASTERN SHORE

In many places ditches were constructed to connect the creeks thereby increasing runoff rates. Dams have been built in several estuaries below and at the head of the tidewater to provide a source of water for crop irrigation during drought periods. This practice in turn has increased the retention time of the runoff water, adding to the ground water recharge.

The climate of the peninsula is temperate; the average annual precipitation is 43 inches. Although this rainfall is equivalent to one half trillion gallons of water per year, very little is usable as a ground water supply since most of the precipitation is lost through runoff, transpiration and evaporation.

The soils of the Eastern Shore are predominately made up of sand, silt and shell fragments. The dominant constituent is sand, which contains varying amounts of finer particles ranging in size from very fine sand to clay. This range and combination of soil types comprise the six soil associations found on the Eastern Shore. In general, the soils are moderately well drained, except in certain sections of the foreland along the Bay associated with Accomack County and along the oceanside of Northampton County. In these locations and a few isolated areas on the upland of both counties the tight soils reduce the amount of rainfall reaching the aquifers, thereby decreasing the recharge rate. Most soils are underlain by a fine-to medium-grained sand which is an excellent medium for providing recharge to the underlying units.

The natural vegetation on the Eastern Shore consist of forest and wetlands. The forests are predominately grown for timber and are located mostly on the poorly drained soils. The wetlands make up a substantial portion of the foreland on the east side of the peninsula and on the bayside along Accomack County.

The population of both counties can be described as rural with one third living in the 19 incorporated towns. Numerous small communities are scattered along the rural routes and U. S. 13. The main concentration of people is adjacent to the railroad and U. S. 13, where most of the commercial and industrial establishments are located. The seafood industry supports small communities along the bay and oceanside and, more recently, a trend is developing towards retirement and recreational communities.

The Eastern Shore derives most of its income from the food processing industry. Seafood, agriculture and the related processing industries have long been an important aspect of the Eastern Shore's economy. Most industrial water use is related to the processing of food products principally seafood, vegetables and poultry.

HYDROLOGIC CYCLE

The peninsula is hydrologically in a unique situation. No major streams or other surface water supplies exist to aid in providing potable water for human needs. The water needs, except for a portion of the irrigation water, are supplied by ground water. This ground water is constantly replenished by rainfall and the scenario in which this operates is called the hydrologic cycle (Figure 2).

The natural system is generally in dynamic equilibrium, however, when man pumps from aquifers, changes in the equilibrium occur. With moderate withdrawals the ground water is adequately recharged but when withdrawals exceed a certain optimum quantity, the aquifer may be harmed and salt water encroachment can occur. This optimum balance between withdrawal and recharge can be defined as the safe yield of the aquifer. Continuous observation of water levels and water quality, specifically with regard to the chloride levels, will ensure that the safe yield is not exceeded. Using aquifer test data, an evaluation of safe yield can be made, however, the exact amount of recharge can not be adequately determined and long term effects from pumpage will be hard to estimate.

GROUND WATER DEVELOPMENT

The principal factors governing the amount of ground water which can be recovered from the waterbearing formations are the texture and stratification of the materials, the arrangement and size distribution of the grains, and the permeability of those formations. A major portion of the subsurface on the Eastern Shore consists of a mixture of silt, sand and shell fragments which results in the formation having a relatively low permeability. Large diameter and multi-screened wells are generally needed to produce quantities larger than 100 gallons per minute. In some areas, formations consist of fine gravel and coarse sand, which can produce well yields of 500 to 750 gpm.

The major pumping centers on the Eastern Shore are confined to five areas; three in Accomack County and two in Northampton County. Figure 3 shows these pumping centers and they are defined by the following areas: Hallwood-Temperanceville, Chincoteague-NASA, Accomac in Accomack County, and Exmore-Willis Wharf, Cape Charles-Cheriton-Oyster in Northampton County. The pumpages presented on Figure 3 are averages obtained from pumpage and use reports submitted by the users and reflect a three year period (1977-1979). Many users, until recently, did not meter their use and the data were submitted as estimates. These estimates, if available, were included to produce the three year average.

As these averages do not reflect the seasonal variations of pumpage, particularly in the vegetable processing industry, they may not indicate the stress placed on the aquifer at certain periods

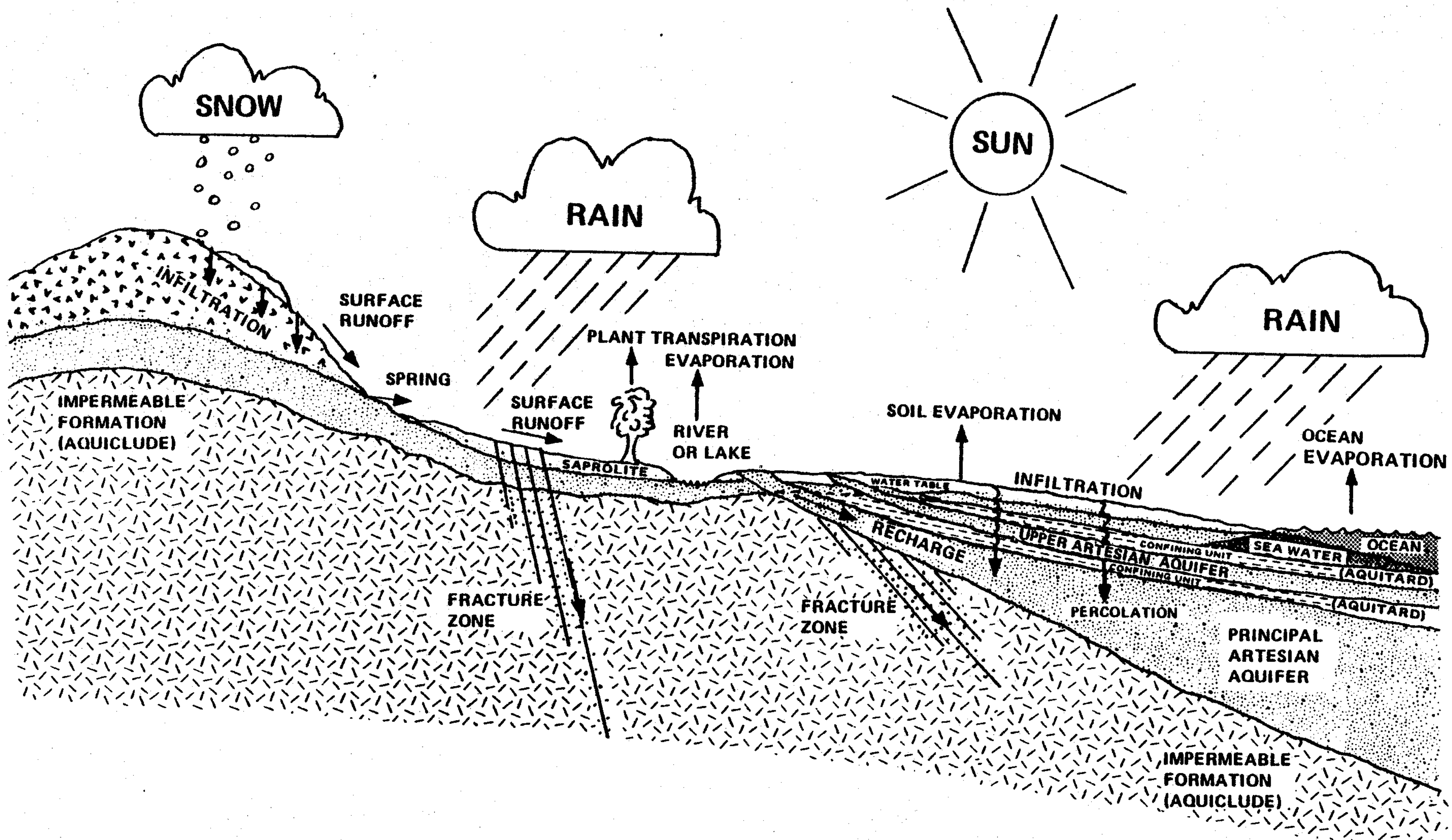
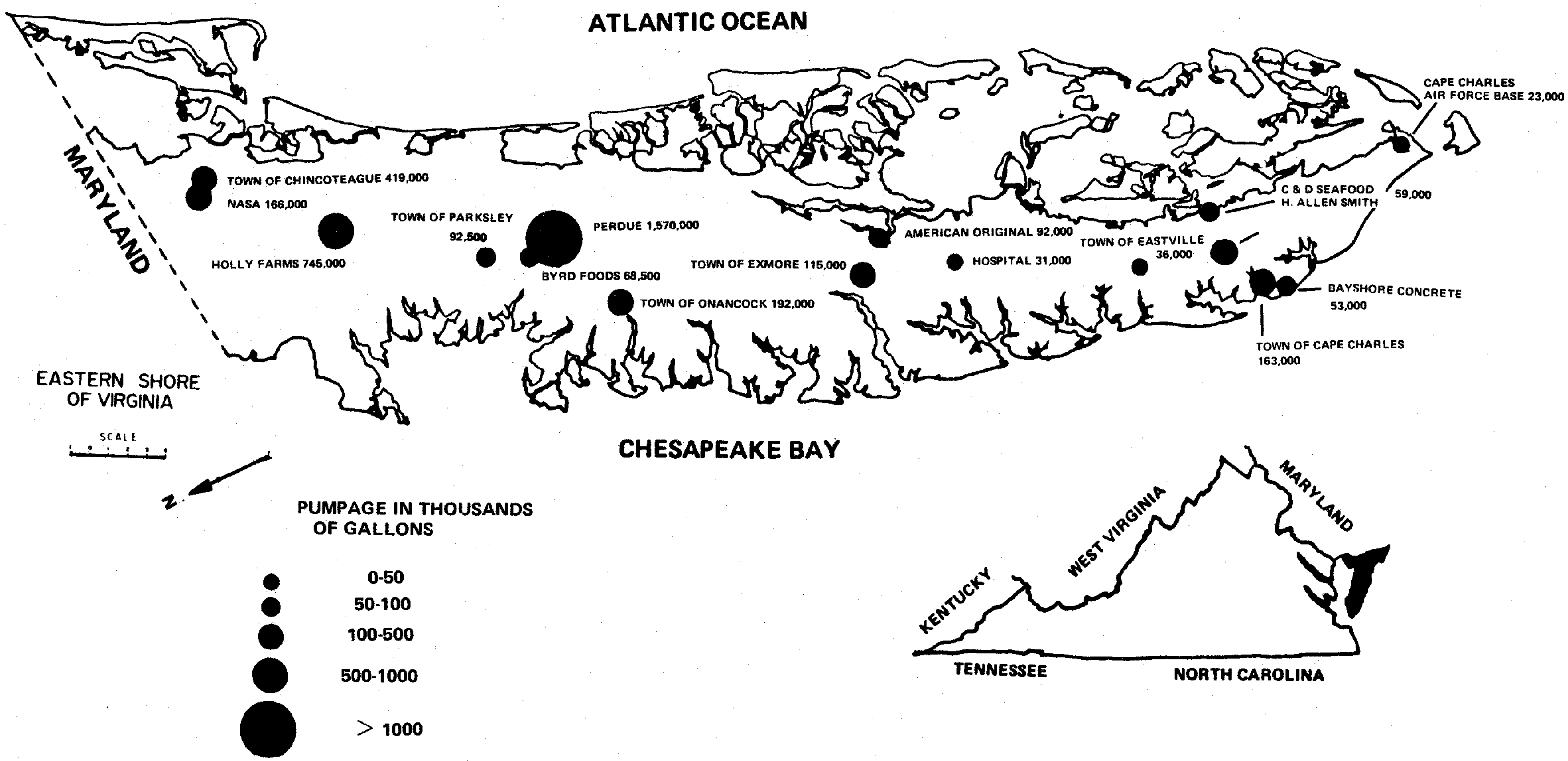


Figure 2. Hydrologic Cycle

SOURCE: STATE WATER CONTROL BOARD – PRO

FIGURE 3. MAJOR PUMPING CENTERS ON THE EASTERN SHORE



of the year (primarily summer and fall). For instance, the given three year average for the Kane Miller Corporation in Cheriton is 0.28 MGD, however, during 1979 withdrawals averaged 0.8 MGD during the fall months, with a peak use of 1.4 MGD occuring during the summer.

Another aspect not evident from the given average pumpage figures is the changes in pumpage which have occured recently. Under the Ground-water Management Area permit system any industry which uses 50,000 gpd or more must apply for a permit to use ground water. When the system went into effect in 1976, ten industries received a grandfathered certificate reflecting their maximum usage. Since that time one new certificate has been issued and four increases have been granted. This represents an increase of 16.7% over the 1976 amount of 8,861,450 gpd total permitted withdrawal and reflects the cumulative maximum the industries can pump in one day. The average pumpage per day is, of course, lower.

Six of the towns have a municipal water service to their residents and have the following daily averages:

Town	Gallons Per Day
Chincoteague	419,000
Parksley	92,500
Onancock	192,000
Exmore	116,000
Eastville	38,000
Cape Charles	165,000

The Town of Chincoteague increases to as much as 585,000 gpd during the summer months. There are a total of twenty-four small public water systems which operate on the Eastern Shore. These are systems which serve subdivisions and trailer parks.

In addition to industrial and domestic uses, irrigation is another major use of ground water. The wells are generally large in diameter, but only draw from the water table aquifer. This use is largely dependent on precipitation and operates primarily during dry periods. No permit is necessary for this use and consequently quantitative information on these systems is not available. However, some of these wells are capable of delivering up to 750 gpm, which is a larger rate than any of the existing industrial or public supply wells.

Domestic withdrawal on the Eastern Shore is scattered throughout the peninsula, concentrated only in the communities without a public system. Total estimated private use, using 1970 population figures, is approximately 3.5 MGD assuming a 100 gpd per person consumption.

The total ground water use on the Eastern Shore is approximately 8.5 MGD, excluding use for irrigation. This amount is only a portion of the total available supply. It is estimated that twice this amount is readily available in the many untapped areas.

In the "Specific Areas" section of this report, geohydrologic cross-sections and pumpage data are given along with some of the pertinent information on the major wells and well fields as well as the analyzes of the pump tests. The demarcation of the salt/fresh water interface is given in the cross sections and an isogram is presented in the quality section of this report. All of this information can be used to derive workable estimates of the potential available yield in these areas. Although approximate yield estimates are given in some instances, it should be noted that only through test drilling and aquifer tests can the necessary quantitative data be provided so that well yields can be predicted for a specified area. Generally, the greater quantities of water are available along the central ridge. The available amount of ground water will diminish towards the ocean and bay. The depth of new wells should be kept far above the bottom salt/fresh water interface to prevent upconing of salt water. Using proper management and development practices, sufficient ground water is available to meet future needs of at least twice the current demand. Continuous monitoring, data gathering and analyses of the ground water system will keep serious problems from developing and allow reliable estimates of water availability to be made.

POTENTIAL AND EXISTING PROBLEMS

In order to effectively manage the ground water on the Eastern Shore, the major impacts from pumping large quantities should be discussed in more detail. The problems can be classified into three main areas: 1) Salt water intrusion; pumping close to the bay or ocean or close to the bottom interface will cause the interface to move towards the well field and eventually contaminate the aquifer. 2) Dewatering; excessive pumping of the aquifer will cause consolidation of the formation making it poorly transmissible and reducing its storage capacity, and 3) Well interference; this is probably the largest problem on the Eastern Shore. Wherever large quantities of water are withdrawn a cone of depression will develop and thus lower the water level in the aquifer. Smaller pumps and shallow wells will not be able to work against the increased drawdown and water cannot be delivered. The only method to solve the loss of water to these smaller water systems is to increase pump size. Usually a new well is also needed. In areas on the Eastern Shore where well interference has been a problem, water well compensation plans have been developed. The larger users have replaced the inadequate pumps and wells with new systems able to withdraw water from the new, artifically lowered, water level.

Proper management techniques can prevent or minimize potential problems. The principal solution to water well interference problems rests in the judicious location of new wells, by placing them outside of current cones of depression. Keeping the depth of the screens well above the salt/fresh interface and maintaining a sufficient lateral distance from the ocean or bay, coupled with good pumping practices will maintain good water quality.

RECOVERY METHODS

Most of the wells on the Eastern Shore are less than -300 feet mean sea level. Below this elevation water becomes unusable because of the high chloride content. Along the bay and ocean the brackish water may occur at a much higher elevation. Several different methods of well construction and means of recovery are used on the Shore. Most commonly a rotary drill is used for all large wells and most domestic wells. Other methods such as jetting and driving wells are also used, but not on a commercial scale.

Most of the water for domestic purposes is recovered through 1-1/4 or 2 inch diameter wells with five feet of screen drawn by an electric centrifugal pump. Two types of systems are commonly employed; the shallow well and the deep well. The shallow well will generally draw water if the water level does not exceed a depth of 20 feet; a deep well hook up is needed in order to withdraw water from depths greater than 20 feet. The latter type of system is generally needed at the higher elevations and in the vicinity of the major well fields. Either of these systems are commonly used for domestic needs although submersible pumps are occasionally used for domestic supply. Most new industrial wells are submersible pumps.

GEOLOGY

The general geology of the Eastern Shore has been described by several investigators such as Sinnott and Tibbetts (1968), Teifke (1973), Brown (1973) and Onuschak (1973). The area of interest for this report confines itself to the geology of Miocene and Pleistocene age. The Miocene has been estimated to lie from a depth of 80 to 800 feet below the Eastern Shore. It is divided into four formations, which in ascending order are the Calvert, Choptank, St. Mary's and Yorktown. The upper portion of the Yorktown may in part be of Pleistocene age. The separation of the different formations is not distinct and is determined largely by the fossil assemblages. No attempt was made to identify the various fossils during this study. The study concerned itself with the strata above -400 feet MSL and the correlation between geohydrologically similar units. These upper 300 feet of strata are part of the Yorktown formation except the upper portion which contains the water table of Pleistocene age.

The lithologic units are quite complex on the Eastern Shore, and can generally be correlated only over short distances before significant changes occur. Attempts to correlate units along a north-south axis generally will be more successful than attempting an east-west correlation. The transgression and regression of the ocean which during Miocene and Pleistocene times occured in an east-west direction created similar lithology in this direction.

Strata of the Miocene units consist of fine gravel, sand, silt, clay and shell fragments which make up the heterogeneous beds of the Miocene. Because of this heterogeneity, gradational changes are common in these units and occur over short distances.

HYDROGEOLOGY

The hydrological characteristics of the formation are strongly influenced by the lithology in that the gradational sequence cause a wide variation in the characteristics of the aquifer. Correlations between different locations are more meaningful if geophysical logs are used as the principal guide. These aquifers are termed, in this report, the Pleistocene and Upper, Middle and Lower units of the Miocene. A clear distinction can generally be made between the Pleistocene and Upper Miocene, and between the Middle and Lower units of the Miocene. See Figures 4 through 8 for thickness of aquifer and top of aquifer. The Pleistocene units are usually fine-to-medium grained sand, separated by layers of silt from the Miocene. The Miocene units are a combination of fine gravel, sand, silt, clay and shell fragments. Silt layers also separate the three units of the Miocene. In several areas the separation between the layers may not be very distinct. Because of the large variations in lithology it can be difficult to distinguish the aquifers since several silt layers may be present in a particular area. Some areas have no distinct silt layer and thus no separation can be made. The lithology of all four units will also change laterally but the change is much more dramatic in an east-west direction, as is demonstrated in the cross-section, than in a north-south direction.

A wide variation in the physical composition of the aquifers exist because of the heterogeneity in the sediments. Aquifer parameters are presented in Table 1 and show the variations which occur on the Eastern Shore. These data are derived from various sources and show that a range in transmissivity (the ease with which water passes through the aquifer) from 1000 to 3800 gpd/ft is common. Large variations exist in the test data obtained from both the pump and recovery portions of the tests as well as from different wells in the same well field. These variations are attributed to technical problems such as partial penetration of the screens in the water bearing formation, slight differences in screen elevations, termination of the test before stable conditions are attained, and the differences in screen and well design. More reliable information is obtained using a production and one or more observation wells, with screens open to the same formation.

WATER QUALITY

Water from each well of the research stations was sampled at the time of construction and analyzed for 25 parameters. Subsequent samples have been taken from each research station. A tabulation of the available analyses are presented with the individual station reports and summarized in Table 2. Table 3 presents the ground water quality standards used by the State Water Control Board.

Some of the common parameters relevant to evaluating a water source in this area are pH, chloride, nitrate/nitrite, sulphate, and iron. The general analyses for these parameters are discussed below.

FIGURE 4. TOP OF UPPER MIOCENE

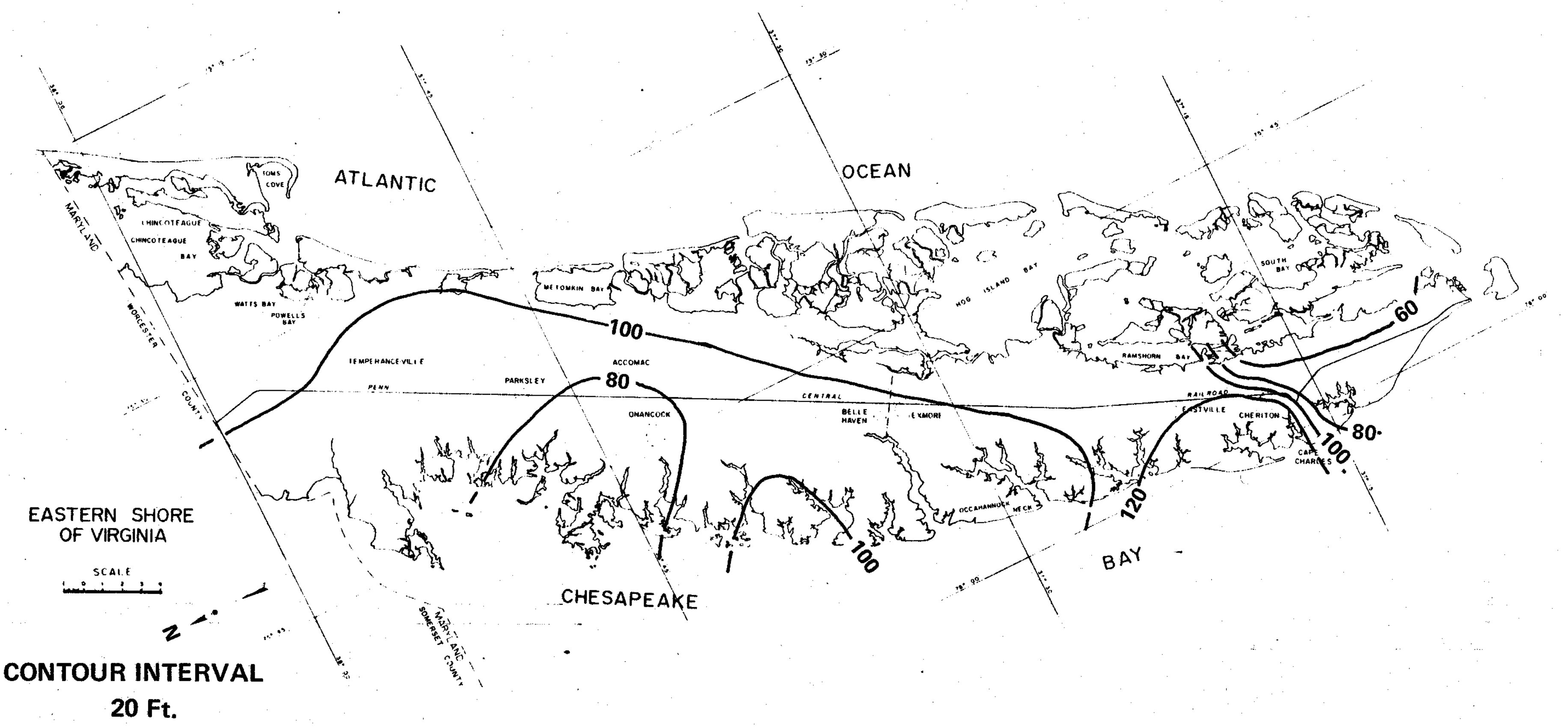


FIGURE 5. THICKNESS OF UPPER MIOCENE

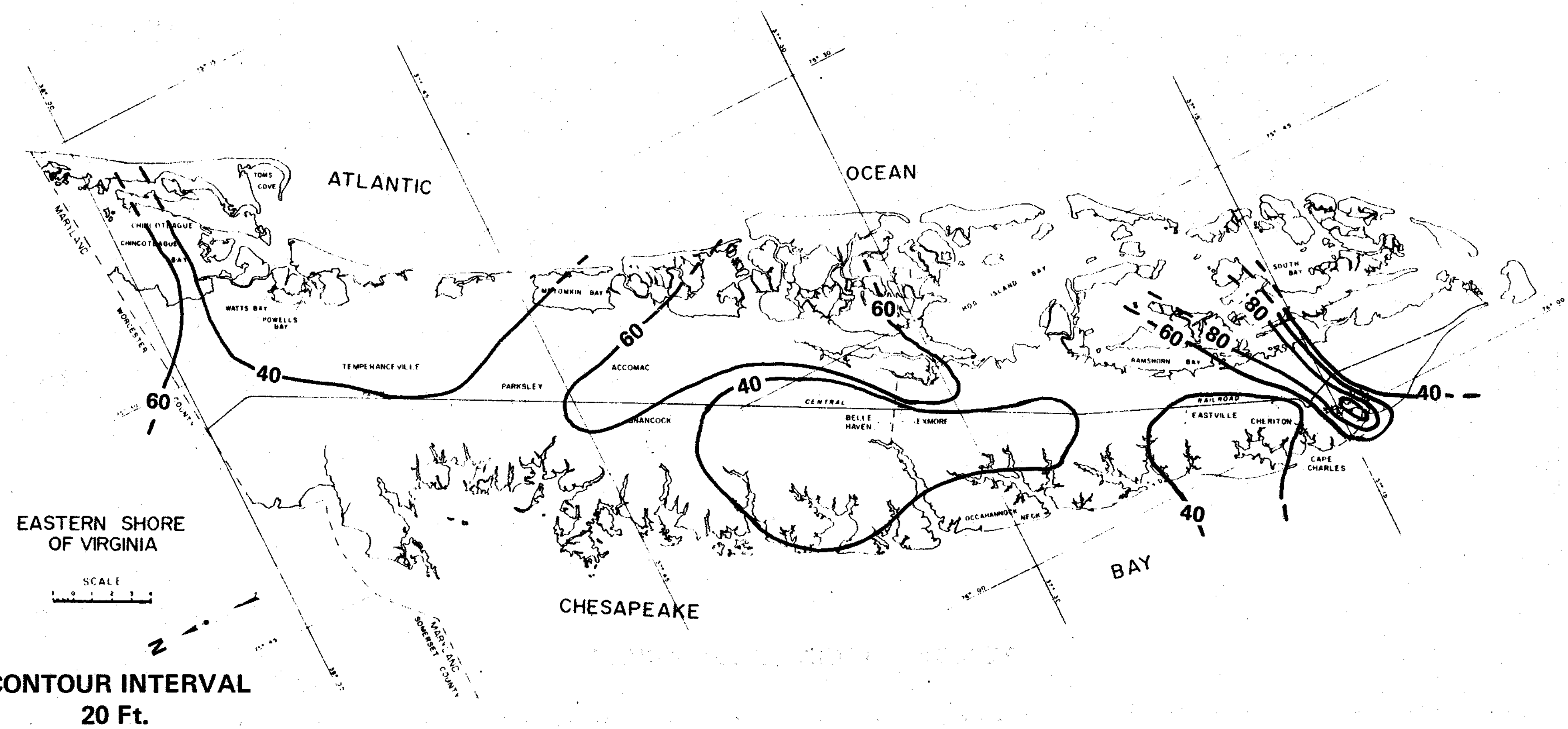


FIGURE 6. TOP OF MIDDLE MIOCENE

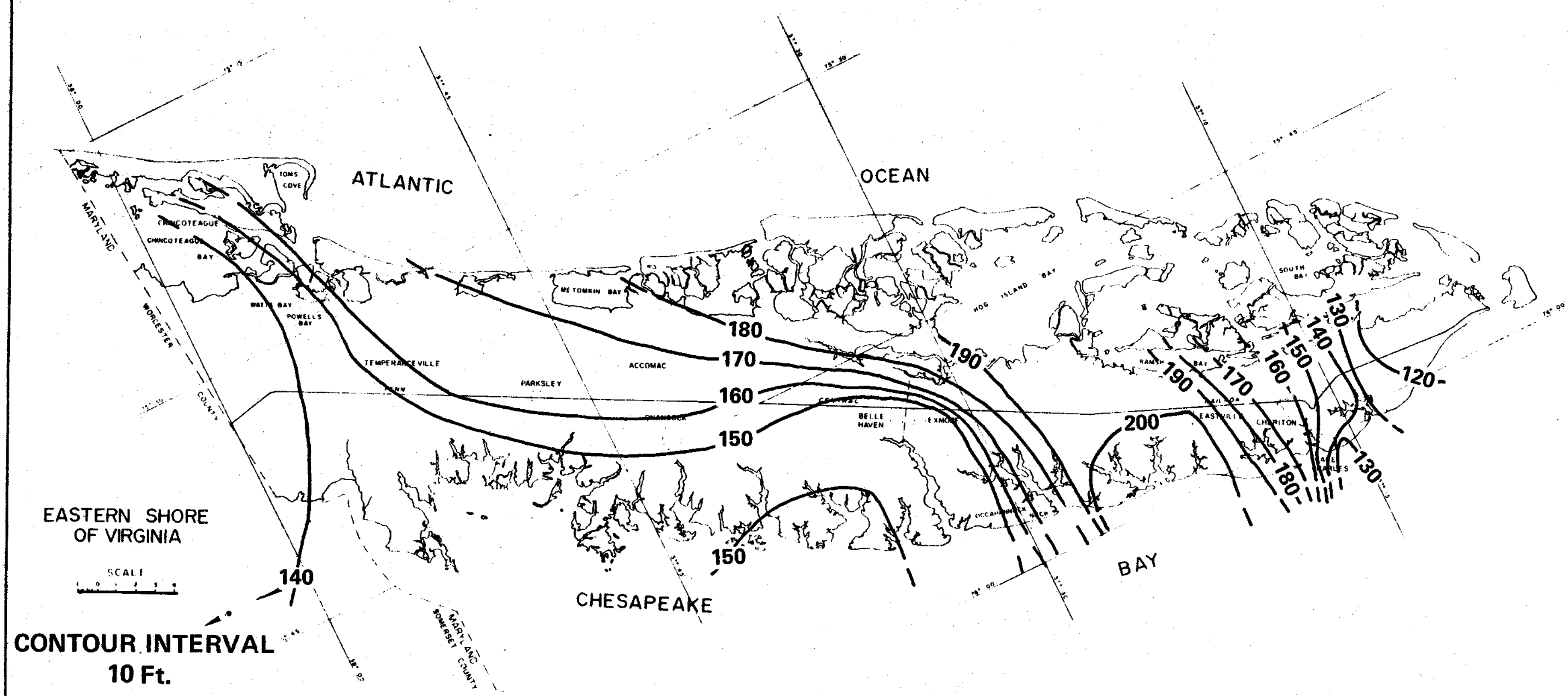


FIGURE 7. THICKNESS OF MIDDLE MIOCENE

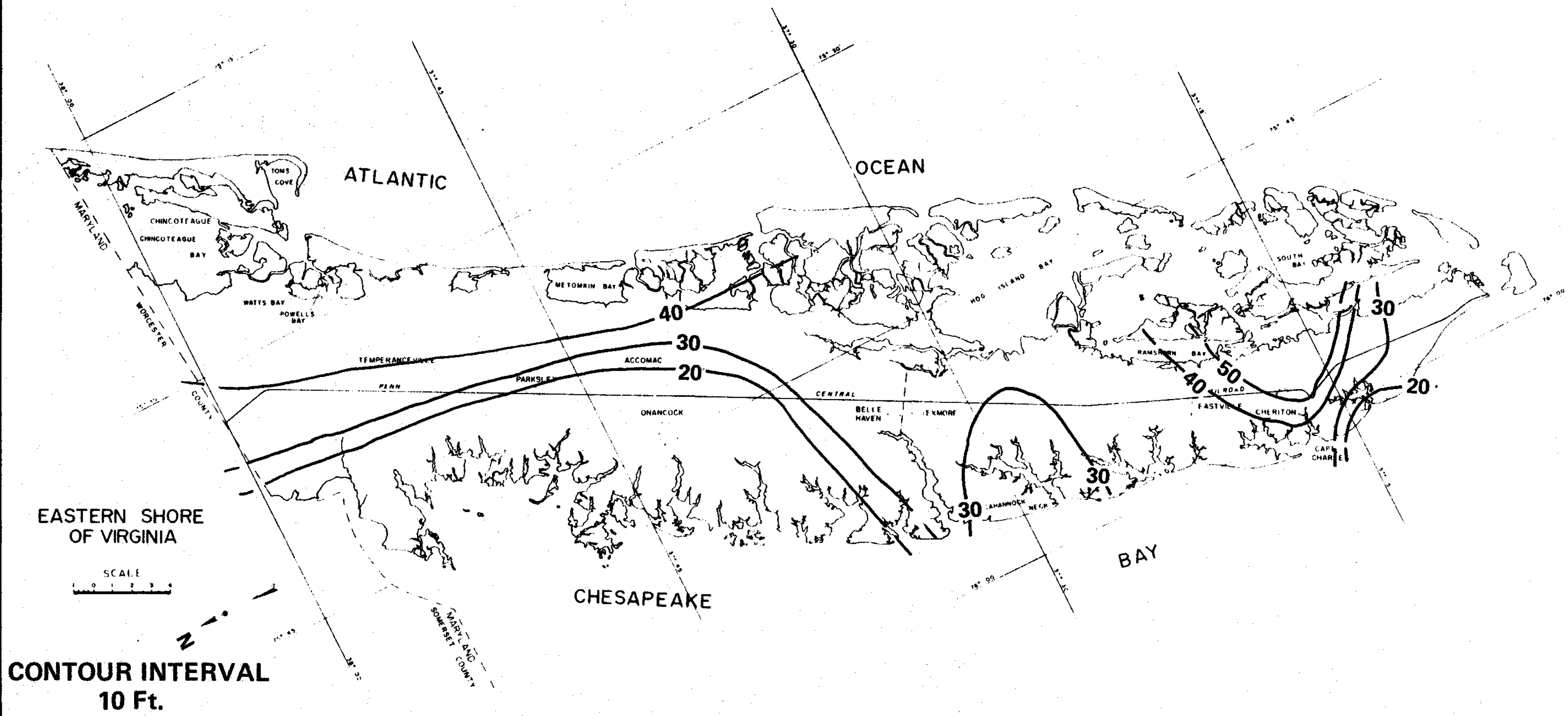


FIGURE 8. TOP OF LOWER MIOCENE

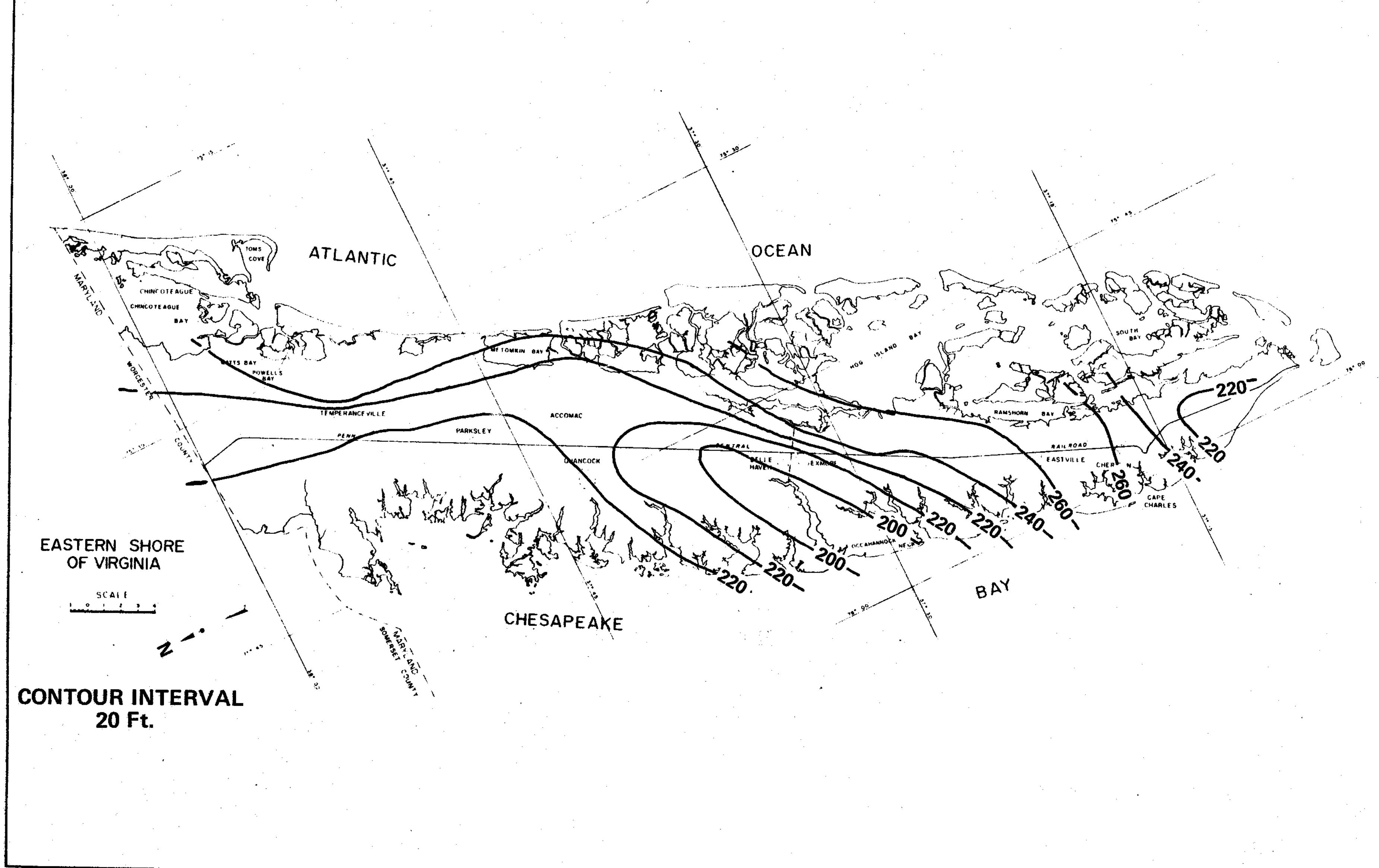


TABLE 1

Aquifer Parameters

Information from driller supplied data

Well No.	Name	Transmissivity (gpd/ft)
		Recovery Jacob
165-1	Northampton-Accomack Hospital	2886
165-39	Exmore Foods	18673
100-9	Holly Farms #4	20592
100-10	Holly Farms #3	19250
100-26	Perdue Foods #2	13549
100-29	Perdue Foods #3	18703
100-30	Perdue Foods #1	6844

Information from Brown & Root pump test

Well No.	Name	Transmissivity (gpd/ft)		Storage Coefficient	
		Pumping		Pumping	
		Theis	Jacob	Theis	Jacob
165-183	Brown & Root 0-2	1700	2600	0.00055	0.00038
165-184	Brown & Root 0-3	3800	4600	0.0013	0.00095
165-186	Brown & Root 0-3	3500	5000	0.00068	0.00046

Information from SWCB pump tests

Well No.	Name	Transmissivity (gpd/ft)		Storage Coefficient
		Pumping Theis	Recovery Jacob	Pumping Theis
100-450	Chincoteague C	8672	12118	0.000095
100-451	Chincoteague D	8228	8213	0.00048
100-28	Town of Chincoteague #4		8904	
165-34	Exmore Foods #4	11684	21450	0.00056
165-33	Exmore Foods #1	19864	26918	
165-29	Exmore Foods #8		20188	
165-157	KMC Foods	10150	10675	0.00026
165-158	KMC Foods	8928		

TABLE 2

CHEMICAL DATA FOR EASTERN SHORE RESEARCH STATIONS

Well No.	Elev.	Aquifer	Date	pH	TDS	Cl	Hrdns	NO2	Fe	Na
101A	-139	U MIO	6-77	7.8	134	8	102	0.09	0.10	7
101A	-139	U MIO	10-79	7.9	162	7	100	0.70	0.29	11
101B	-207	M MIO	6-77	7.7	160	16	110	0.37	0.90	9
101B	-207	M MIO	10-79	7.9	164	7	106	0.05	0.16	11
101C	-279	L MIO	6-77	8.0	383	129	131	0.26	0.10	105
101C	-279	L MIO	10-79	8.0	168	8	98	0.05	0.08	13
102A	-143	U MIO	6-77	7.7	314	52	91	0.05	0.60	78
102A	-143	U MIO	5-79	8.2	343	49	90	0.05	0.40	55
102B	-209	M MIO	6-77	7.9	763	350	105	0.05	0.10	303
102B	-209	M MIO	5-79	8.3	863	333	102	0.05	0.30	220
102C	-295	L MIO	6-77	8.0	3819	2217	357	0.05	0.60	1547
102C	-295	L MIO	5-79	8.2	3967	2147	376	0.05	0.50	512
103A	- 17	PLEIS	9-77	6.1	442	43	224	12.00	1.00	23
103A	- 17	PLEIS	5-79	6.8	508	30	229	17.60	0.16	8
103B	-112	U MIO	9-77	7.7	215	24	116	0.31	0.20	30
103B	-112	U MIO	5-79	7.9	221	24	141	0.50	0.04	12
103C	-215	L MIO	9-77	8.3	937	297	46	0.60	0.10	393
103C	-215	L MIO	5-79	8.4	877	244	57	0.05	0.06	275
104A	-107	U MIO	10-77	7.5	266	155	135	0.05	0.30	46
104A	-107	U MIO	9-79	7.9	192	31	103	0.05	0.20	30
104A	-107	U MIO	8-80	7.5	181	24	98	0.05	0.23	16
104B	-207	M MIO	10-77	7.6	169	72	99	0.05	0.30	27
104B	-207	M MIO	9-79	7.8	160	31	91	0.05	-	-
104B	-207	M MIO	8-80	7.6	161	20	87	0.05	0.15	14
104C	-277	L MIO	10-77	7.9	976	903	210	0.05	1.00	296
104C	-277	L MIO	9-79	7.8	681	293	176	0.05	0.23	208
104C	-277	L MIO	8-80	7.6	531	207	152	0.05	0.20	111
104S	- 3	PLEIS	10-77	7.0	1269	66	150	6.90	6.40	11
104S	- 3	PLEIS	8-80	6.4	704	43	124	9.00	-	-
104S	- 3	PLEIS	8-80	5.9	345	35	132	7.50	3.70	16
105A	- 95	U MIO	6-78	7.7	217	20	122	0.08	-	-
105A	- 95	U MIO	8-80	7.4	228	25	138	0.05	0.26	15
105B	-161	M MIO	6-78	8.0	193	-	34	0.01	-	-
105B	-161	M MIO	8-80	7.9	197	13	42	0.05	0.14	51
105C	-250	L MIO	6-78	8.4	594	-	24	0.01	-	-
105C	-250	L MIO	8-80	8.3	523	75	26	0.05	0.10	179
106A	- 29	PLEIS	9-77	6.8	472	178	123	0.05	21.00	94
106A	- 29	PLEIS	8-80	6.2	-	92	78	0.05	-	-
106B	- 87	U MIO	9-77	7.0	294	33	204	0.05	2.80	28
106B	- 87	U MIO	8-80	7.4	-	41	202	0.05	2.70	23
106C	-168	M MIO	9-77	7.9	818	313	185	0.05	1.00	300
106C	-168	M MIO	8-80	7.8	-	318	162	0.05	0.18	200

TABLE 2 continued

CHEMICAL DATA FOR EASTERN SHORE RESEARCH STATIONS

Well No.	Elev.	Aquifer	Date	pH	TDS	Cl	Hrdns	NO_2	Fe	Na
107A	-125	U MIO	9-77	7.2	100	7	62	0.05	5.80	9
107A	-125	U MIO	10-79	7.0	-	9	72	0.05	1.50	11
107B	-191	M MIO	9-77	8.0	150	9	116	0.05	0.20	9
107B	-191	M MIO	10-79	7.9	209	17	114	0.05	0.07	12
107C	-295	L MIO	9-77	8.7	209	16	132	0.25	-	-
107C	-295	L MIO	10-79	7.7	153	10	90	0.05	0.18	21
108A	+ 2	PLEIS	9-78	7.6	108	17	47	0.05	1.10	8
108A	+ 2	PLEIS	9-79	6.5	103	16	4	0.05	-	-
108A	+ 2	PLEIS	8-80	5.7	-	6	54	0.05	0.86	7
108B	-128	U MIO	9-78	8.0	180	10	110	1.03	0.10	9
108B	-128	U MIO	8-80	7.6	-	10	96	0.05	0.14	10
108C	-232	L MIO	9-78	8.3	327	39	40	0.44	0.10	107
108C	-232	L MIO	8-80	7.8	149	12	112	0.05	1.31	14
109A	-113	U MIO	6-78	8.0	200	-	125	-	-	-
109A	-113	U MIO	10-79	8.1	390	10	130	0.05	4.42	10
109A	-113	U MIO	8-80	7.7	199	7	125	-	1.03	10
109B	-211	L MIO	6-78	8.2	433	-	39	-	1.10	157
109B	-211	L MIO	8-80	8.0	269	9	42	0.05	0.09	79
109C	-273	L MIO	6-78	8.9	32130	-	58	-	0.20	580
109C	-273	L MIO	8-80	8.2	683	515	70	0.05	0.16	555
109S	- 13	PLEIS	6-78	7.7	143	13	58	-	10.10	14
109S	- 13	PLEIS	8-80	7.0	-	19	96	0.05	0.42	13
110A	-115	U MIO	1-79	8.0	262	11	70	0.05	0.88	62
110A	-115	U MIO	8-80	7.8	289	13	68	0.05	0.38	64
110B	-163	M MIO	1-79	8.2	551	62	34	0.05	0.33	212
110B	-163	M MIO	8-80	8.1	559	66	30	0.05	0.03	199
110C	-225	L MIO	1-79	8.0	2803	126	368	0.05	2.83	891
110C	-225	L MIO	8-80	7.9	1740	790	158	0.05	0.32	500
110S	- 21	PLEIS	1-79	6.4	117	13	16	0.05	2.41	11
110S	- 21	PLEIS	8-80	5.8	79	15	20	1.75	2.17	8
111A	-130	U MIO	6-79	8.1	143	8	109	0.05	2.10	26
111A	-130	U MIO	8-80	7.7	179	8	104	0.05	0.60	110
111B	-260	L MIO	6-79	8.1	137	28	118	0.05	0.10	28
111B	-260	L MIO	8-80	7.7	183	9	94	0.05	0.24	8
111C	-310	L MIO	6-79	8.2	700	383	199	0.05	0.30	210
111C	-310	L MIO	8-80	7.8	1350	640	258	0.05	5.30	350
111S	- 50	PLEIS	6-79	7.9	142	13	89	0.05	0.50	24
111S	- 50	PLEIS	8-80	8.0	140	15	88	0.05	0.22	11
112A	-100	U MIO	7-79	8.0	274	11	146	0.08	1.00	24
112A	-100	U MIO	8-80	7.7	231	12	152	0.05	0.17	11
112B	-175	M MIO	7-79	8.1	280	35	118	0.05	0.37	50
112B	-175	M MIO	8-80	7.9	251	35	110	0.05	0.20	40
112C	-278	L MIO	7-79	8.3	3076	1603	305	0.05	0.70	440
112C	-278	L MIO	8-80	7.8	3102	1510	320	0.05	3.90	105
112S	- 12	PLEIS	7-79	6.5	168	23	54	1.90	0.80	30
112S	- 12	PLEIS	8-80	5.8	121	18	52	0.80	0.80	12
113A	- 93	U MIO	2-80	7.9	187	26	88	0.05	1.20	21
113A	- 93	U MIO	8-80	7.5	186	27	86	0.05	0.66	21

TABLE 2 continued

CHEMICAL DATA FOR EASTERN SHORE RESEARCH STATIONS

Well No.	Elev.	Aquifer	Date	pH	TDS	Cl	Hrdns	NO_2	Fe	Na
113B	-198	L MIO	2-80	8.4	2000	2000	287	0.10	18.00	900
113B	-198	L MIO	8-80	7.8	2936	1480	290	0.05	5.30	86
113C	-263	L MIO	2-80	8.5	6030	6200	706	0.17	10.30	1956
113C	-263	L MIO	8-80	7.7	6494	7400	780	0.18	0.40	1970
114A	-110	U MIO	2-80	6.3	28	4	18	0.05	0.06	4
114B	-180	M MIO	2-80	7.9	180	14	118	0.05	0.05	10
114C	-265	L MIO	2-80	7.9	132	12	88	0.06	0.05	8
114C	-265	L MIO	8-80	7.7	130	10	90	0.75	0.16	5
114S	+ 10	PLEIS	2-80	6.4	180	14	98	10.00	0.04	8
114S	+ 10	PLEIS	8-80	6.4	201	21	98	0.23	0.01	6
115A	- 24	PLEIS	3-81	6.9	169	35	66	1.50	0.50	20
115A	- 24	PLEIS	5-81	6.2	2752	20	180	1.00	3.50	13
115A	- 24	PLEIS	8-81	6.1	12	14	62	2.40	42.00	14
115B	-114	U MIO	3-81	7.5	239	28	98	0.05	0.40	35
115B	-114	U MIO	5-81	7.9	208	23	86	0.05	0.05	27
115C	-199	M MIO	3-81	7.8	348	79	186	0.05	0.60	44
115C	-199	M MIO	5-81	7.7	327	77	173	0.05	0.50	44
115D	-223	M MIO	3-81	7.8	476	135	128	0.10	1.20	120
115D	-244	L MIO	5-81	7.9	448	19	68	0.05	3.50	12
115E	-254	L MIO	11-81	8.1	444	134	217			

TABLE 3

GROUNDWATER STANDARDS BY PHYSIOGRAPHIC PROVINCE				
CONSTITUENT	CONCENTRATION			
	Coastal Plain	Piedmont & Blue Ridge	Valley & Ridge	Cumberland Plateau
pH	6.5-9	5.5-8.5	6-9	5-8.5
Ammonia Nitrogen	0.025 mg/l	0.025 mg/l	0.025 mg/l	0.025 mg/l
Nitrite Nitrogen	0.025 mg/l	0.025 mg/l	0.025 mg/l	0.025 mg/l
Nitrate Nitrogen	5 mg/l	5 mg/l	5 mg/l	0.5 mg/l

GROUNDWATER STANDARDS–STATEWIDE		
CONSTITUENT	CONCENTRATION	
Sodium	270	mg/l
Foaming Agents as Methylene blue Active Substances	0.05	mg/l
Petroleum hydrocarbons	1	mg/l
Arsenic	0.05	mg/l
Barium	1.0	mg/l
Cadmium	0.0004	mg/l
Chromium	0.05	mg/l
Copper	1.0	mg/l
Cyanide	0.005	mg/l
Lead	0.05	mg/l
Mercury	0.00005	mg/l
Phenols	0.001	mg/l
Selenium	0.01	mg/l
Silver	None	
Zinc	0.05	mg/l
Chlorinated Hydrocarbon Insecticides		
Aldrin/Dieldrin	0.003	ug/l
Chlordane	0.01	ug/l
DDT	0.001	ug/l
Endrin	0.004	ug/l
Heptachlor	0.001	ug/l
Heptachlor Epoxide	0.001	ug/l
Kepone	None	
Lindane	0.01	ug/l
Methoxychlor	0.03	ug/l
Mirex	None	
Toxaphene	None	
Chlorophenoxy Herbicides		
2, 4-D	0.1	mg/l
2, 4, 5-TP	0.01	mg/l
Radioactivity		
Gross Beta	1000	pc/l
Radium 226	3	pc/l
Strontium 90	10	pc/l

The ground water on the Eastern Shore generally has a pH ranging from 7 to 8.5 except near the surface in the water table aquifer where it tends to be acidic. The higher pH values are caused by the water's reaction with the shell fragments in the soil which also contributes to the high alkalinity/acidity values and the hardness of the water which are measured as values of $CaCO_3$.

Parameters which cause the water to be unsuitable are chloride, nitrogen, sulphate and iron. Chloride is the parameter which is the determination of the salt/fresh water interface. A value of 250 mg/l is used as a drinking water standard and is regarded as defining the interface; above 250 mg/l the salt content becomes noticeable to taste. The interface is shown in Figure 9.

Nitrate was found in several of the shallow supply wells which are screened in the upper portion of the water table aquifer. This parameter is generally associated with pollution and on the Eastern Shore these values are possibly caused by fertilizer from farming practices or by septic waste leaching to the ground water. The highest value found in an observation well was 17.5 mg/l (Well A, Station 77-103). This value is above drinking water standards. Proper management practices for the disposal of organic waste and in the application of fertilizer would reduce the potential for contamination.

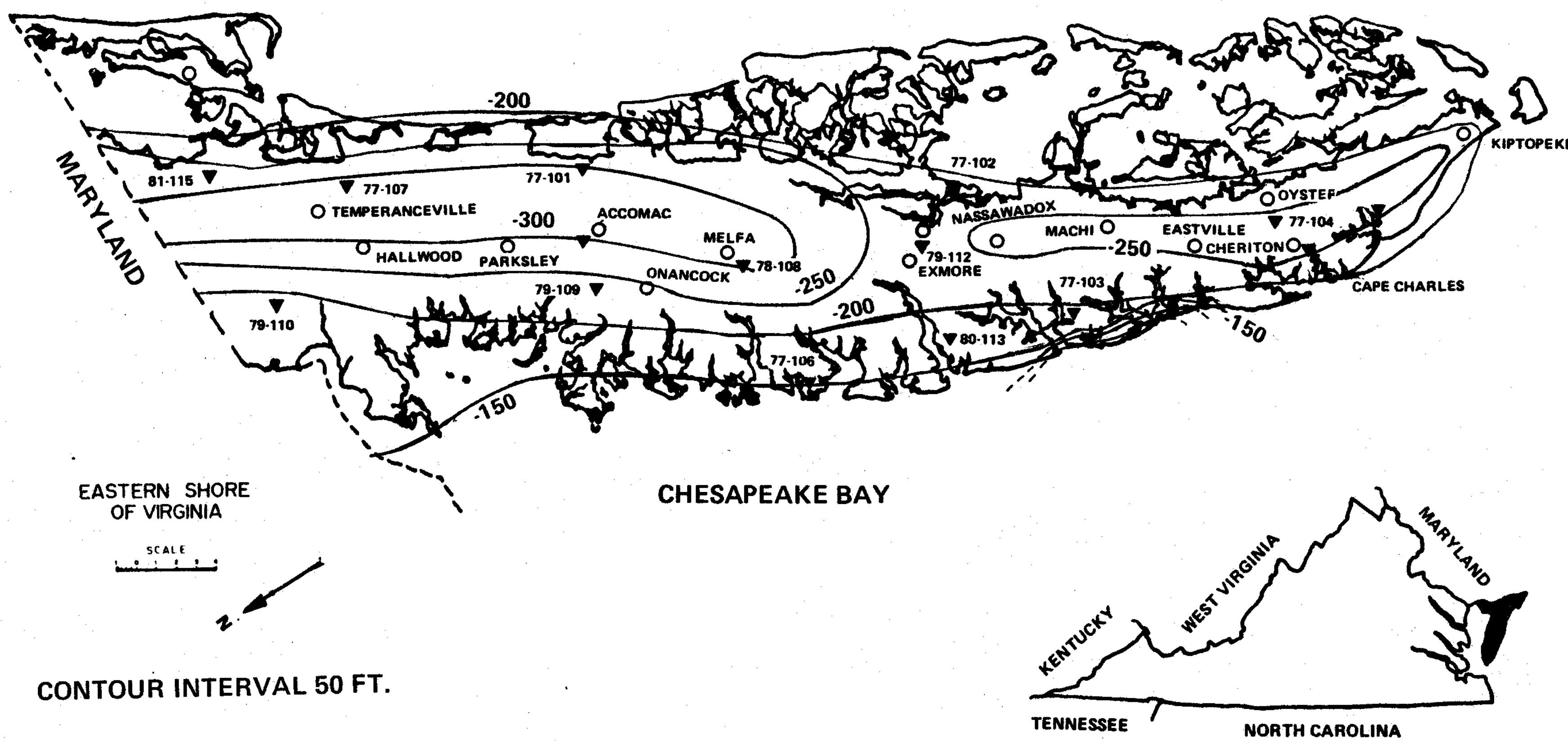
Sulphates present an odor problem in some areas. The values found in the observation wells are within ground water quality standards. It is primarily an aesthetic problem caused by bacterial reduction of organic matter in the formation. Iron values are high in the upper aquifers but generally drop to acceptable limits in the middle and lower units of the Miocene. They can be very high locally; for example at station 77-106 a value of 21 mg/l was found in the water from Well A.

SPECIFIC AREA INFORMATION - KIPTOPEKE TO CHERITON

Hydrologic data for the Kiptopeke/Cheriton area were obtained from the research stations and existing wells. Cross-sections for this region are presented in Figures 11 and 12. For locations of these and subsequent cross-sections see Figure 10. Additional cross-sections were made by consultants preparing the environmental impact statement for the proposed Brown and Root facility which was to be located south of Cape Charles.

An evaluation of the area can be described from south to north as follows. Data are sparce south of well number 165-4 (USGS #1 test well) and are limited to driller information from existing wells. The first control data are derived from three wells, each 60' deep, belonging to the Air Force Base at Cape Charles. The eastern-most well on occasion shows an increase in chloride during the summer months. This increase can be interpreted as movement of the salt/ fresh water interface. Potable water can be obtained on a continual basis from the other two wells. Withdrawal is generally less than 50,000 gpd.

FIGURE 9. SALT/FRESH WATER INTERFACE
DEPTH TO 250 MG/L ISOCHLOR



CONTOUR INTERVAL 50 FT.

FIGURE 10.CROSS SECTION LOCATIONS

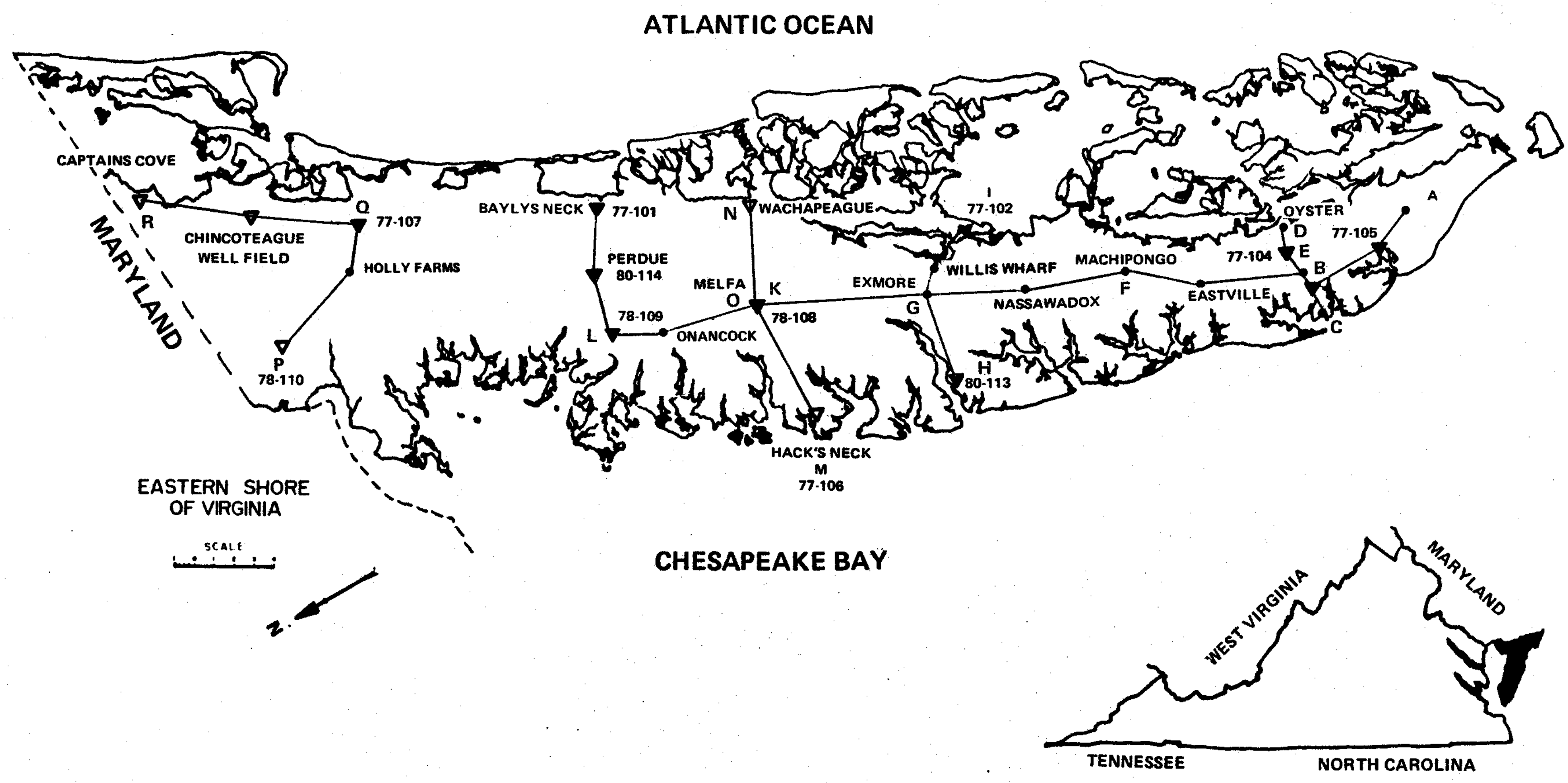


FIGURE 11. HYDROGEOLOGIC CROSS–SECTION CAPEVILLE–CHERITON

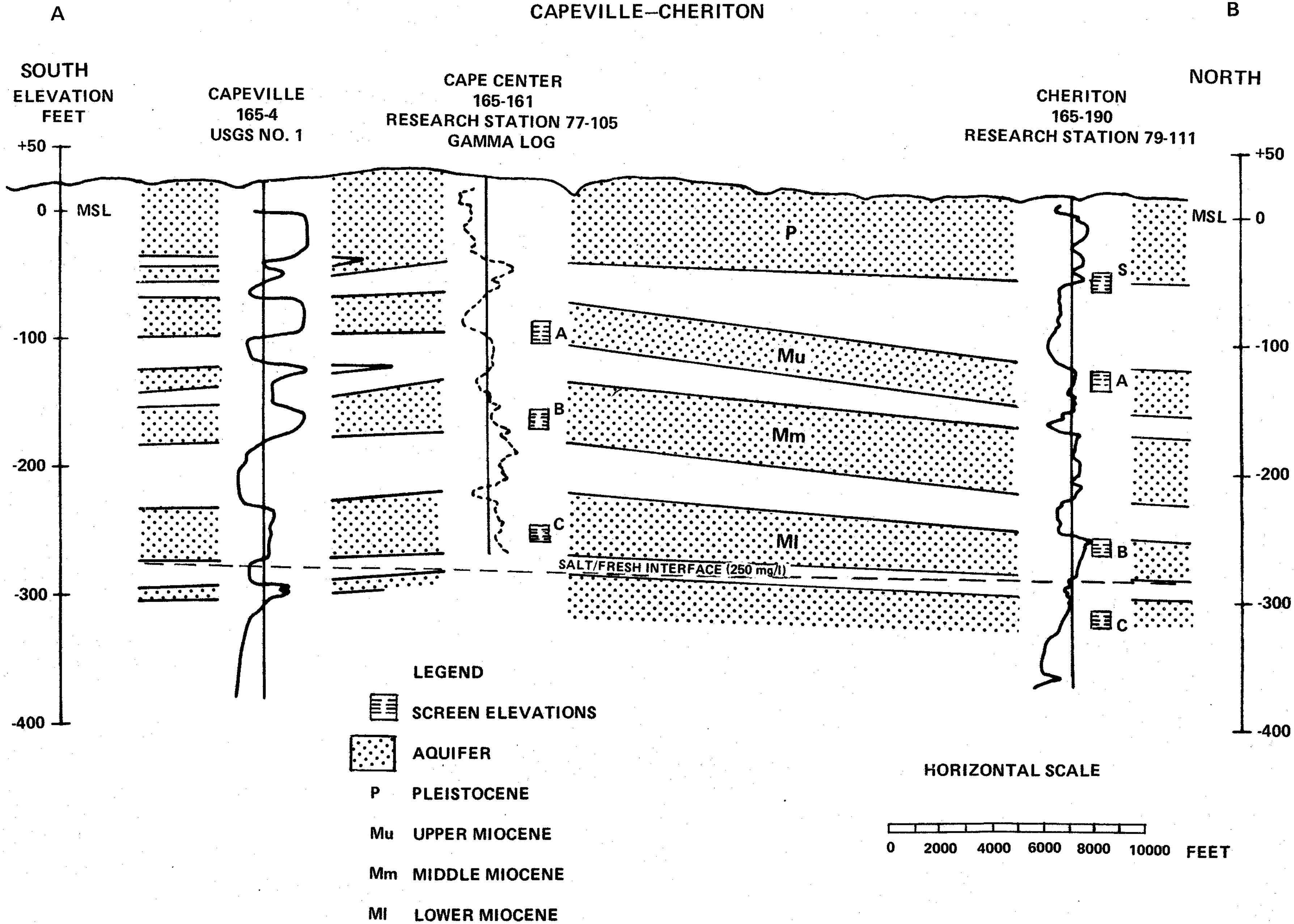
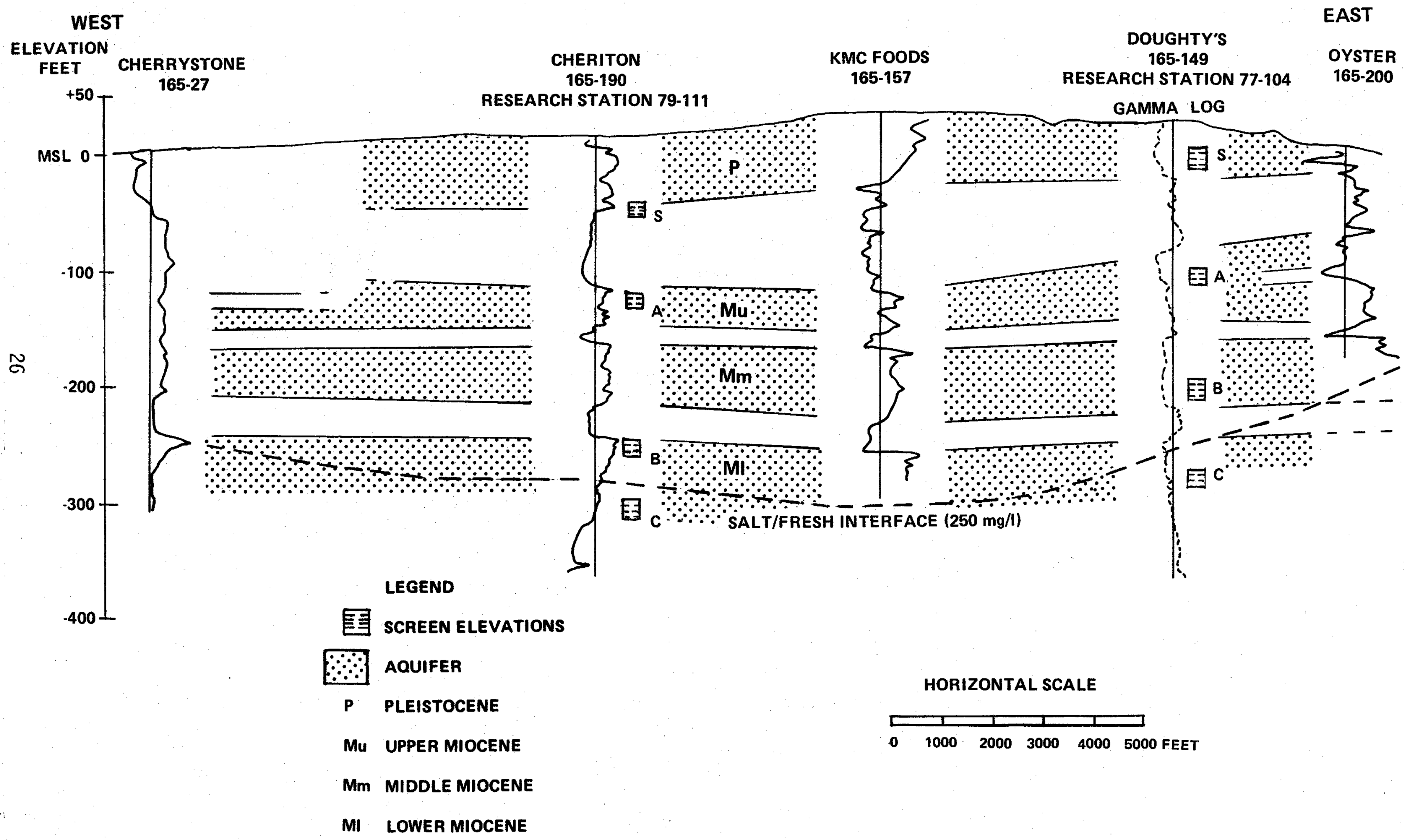


FIGURE 12. HYDROGEOLOGIC CROSS–SECTION
CHERRYSTONE–OYSTER



The elevation of availability of potable water increases toward the central portion of the area, north of Kiptopeke. Here potable water is available to elevations of -200 feet MSL, but the principal source of water is obtained at elevations ranging from -80 to -150 MSL. Water quality is good but is moderately hard and high in iron locally.

North of Capeville, data are available from several wells and the aquifers have been delineated in the cross-sections. The area has been subdivided into four major units; one is of Pleistocene age and the remaining three are of Miocene age. The Pleistocene (P) is usually under unconfined conditions, but when silt and clay are present the aquifer may behave as a semi-confined unit. The Miocene units underlie the Pleistocene and behave under confined to semi-confined conditions. The three units are all members of the Yorktown Formation of Miocene age and have been called, Upper (Mu), Middle (Mm), and Lower (Ml), Miocene in this report.

The upper unit (Mu) underlies an aquitard of considerable thickness (up to 100 feet) in the northern and central portion of the region. There are several water bearing zones within this aquitard but these are probably local and discontinuous. The Mu unit is very productive in the region and it is the most widely used unit for domestic wells. A pump test performed on a 15" diameter irrigation well near Cape Center yielded 750 gpm, the highest single yield obtained on the Shore. This zone consists of coarse sand, fine gravel and shell fragments; northward it grades into fine sand and shell but remains a productive unit. The middle unit (Mm) is separated from the upper unit (Mu) by a thin aquitard which is generally 15 feet thick. The water quality is good, with soft to moderately hard water and low chlorides. This unit consists mostly of shell fragments and fine to medium sand. It is separated from the lower unit (Ml) by an aquitard which is clayey and therefore fairly impervious. The three units of the Miocene are used extensively by the industrial and municipal users. Wells are generally multi-screened in the three aquifers and are capable of producing at least 250 gpm. Because of these production wells, several cones of depression have developed, especially in the northern portion of the region. On the bay side two cones are associated with wells from the town of Cape Charles and Bayshore Concrete. In the central portion, a cone is found under the well field of H. Allen Smith and C & D Seafood. Problems concerning salt water intrusion or lack of available quantity have not been found with any of these cones and with current pumping demand, none is suspected. The principal limitations for additional development of these aquifers are due to the lack of knowledge concerning the extent of the fresh water under the bay and the ocean and the amount of recharge which takes place. Discharge of freshwater to the ocean is probably taking place from most of the units, especially during the winter months, and therefore it is suspected that the salt/fresh water interface extends a sufficient distance off shore to sustain current pumpage.

Withdrawals from the northern portion, Cape Charles-Cheriton-Oyster, average 550,000 gpd with a substantial increase occurring during parts of the summer caused by an increase in withdrawals by KMC Foods. In the central and southern portion withdrawal is for public, domestic and some commercial purposes. The largest user is the Cape Charles Air Force Base which pumps an average of 23,000 gpd. Other establishments use less than half this amount.

Aquifer data in this area are derived from the pump tests done for the then proposed Brown and Root facility in Cape Charles, for C & D Seafood and H. Allen Smith in Oyster and at the KMC plant in Cheriton. Transmissivity value for the water table aquifer was calculated to be approximately 30,000 gpd/ft using specific capacity data obtained from a large irrigation well located near Cape Center. This value corresponds to those found in the western portion of the Brown and Root site. The Miocene aquifers are under artesian conditions and are less productive.

Transmissivity values for the Miocene were calculated to be 1700 gpd/ft at Brown and Root, 2000 gpd/ft at Oyster and 10,000 gpd/ft at KMC. The unit tested in the first two cases corresponds to the Middle Miocene unit (Mm). A multi-screened wells was used at the KMC plant with screens open in the Mu, Mm and Ml. The upper unit was found to be slightly more productive at the Brown and Root site with the transmissivity value averaging 3650 gpd/ft.

Although the Miocene aquifers have lower transmissivity values, a yield of 250 gpm per well can be realized in most areas of this region provided the wells are properly constructed. Higher quantities of water can be obtained from the water table aquifer, but the water quality may not be desirable. Appendix A contains the data from the KMC pump test. A transmissivity value of 10,000 gpd/ft and a storativity value of .0002 were used to construct a distance drawdown graph (Figure 13). Different pumping values were used to construct a family of curves. These curves can be used to estimate drawdowns as follows: For a withdrawal of 1,180,800 gpd a drawdown of 50 feet is expected 500 feet away from the well. These values can be extended to well fields if only large distances are used. For instance, if a well field pumps 1,440,000 gpd a drawdown of 17 feet is expected at a distance of 4,000 feet. Although these curves were developed for the KMC well field, they can be used for planning purposes in the region if similar well systems are planned. Figure 14 shows water levels using 1,180,800 gpd (800 gpm) in the Cheriton area. Pump test data and analyses of the KMC pump test are presented in Appendix A.

The peninsula narrows south of Capeville and the salt/fresh water interface is located closer to the central ridge. Because of these constraints a diminishing volume of potable water is available.

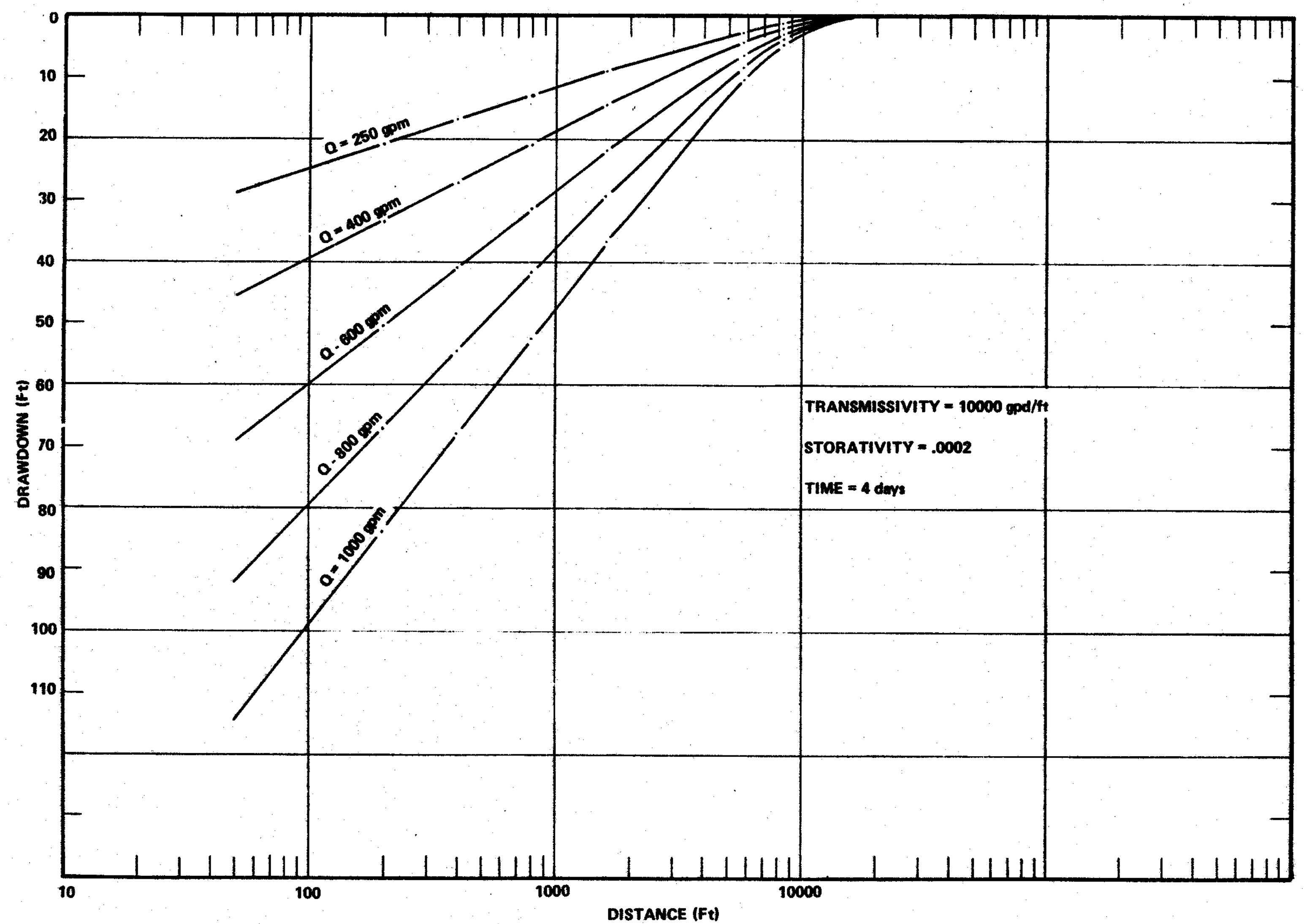


FIGURE 13. DISTANCE-DRAWDOWN GRAPH, KANE-MILLER CORPORATION

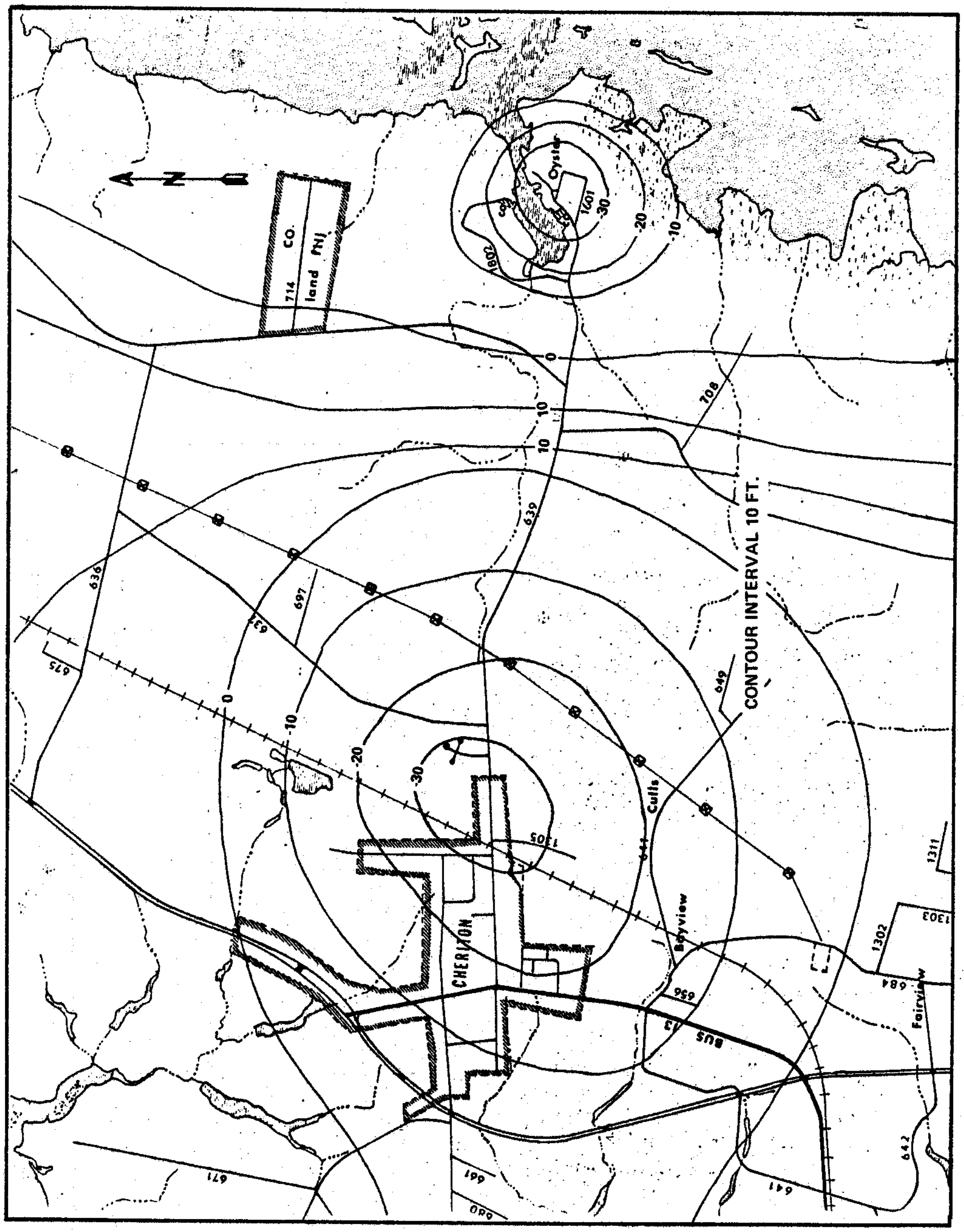


FIGURE 14. WATER LEVELS, CHERITON AREA

SPECIFIC AREA INFORMATION - CHERITON TO MACHIPONGO

A cross-section of this region is shown in Figure 15. The four units identified in the Kiptopeke-Cheriton region continue northward. Although no deep hydrogeological information is available near Machipongo, the units can be correlated using existing well depth and driller's log information. The Pleistocene aquifer increases in total thickness north of Cheriton and reaches an elevation of -70 ft (MSL) at well 165-19. Two industrial supply wells at this location yield 180 and 300 gpm; the more productive well of the two (165-19) is multi-screened to an elevation of -266 feet (MSL) with a total of 25 feet of screen. This well produces from the Mm and the Ml which are the more productive aquifers. Indications are that the Pleistocene is also productive. The supply wells for the Town of Eastville draw from the lower part of the Pleistocene and the upper unit of the Miocene and can produce approximately 100 gpm. Domestic and public use are the primary withdrawals in this region and total about 477,000 gpd. This yield is well under the available yield. The Town of Eastville withdraws an average of 36,000 gpd and is the largest user. A Certificate of Groundwater Right for 441,000 gpd was issued in 1977 for withdrawals by Virginia Agricultural Products (165-19 and 165-18) but the plant is no longer in operation.

A supply of good quality water is available from the water table aquifer. The aquifers here and south of Cheriton are hydrologically similar; yields of 250 gpm can be expected in multi-screened wells along the central ridge and a withdrawal of 500,000 gallons per day should not cause excessive drawdowns to be detrimental to the aquifer. Effects on the water level should be similar as those given for the Cheriton area.

SPECIFIC AREA INFORMATION - MACHIPONGO TO EXMORE

Several cross-sections are available for this area. Figure 16 covers the area from Machipongo to Exmore Foods along the central ridge. Figure 17 was drawn in an east-west direction through Exmore and extends from the bay to the ocean. The same four hydrologic changes take place. These changes take place primarily in an east-west direction and were caused by the lateral shoreline changes which occured during the depositional sequence of Miocene time. Logs from research station 77-102 show that the Mm unit has been replaced by a thick aquitard and the salt/fresh water interface falls in the Ml unit at this station. Quality samples taken in 1977 and 1978, respectively, had Cl- values of 297 and 244 mg/l respectively. These data show that on Church Neck, west of research station 77-103, fresh water is not available below an elevation of -140 feet. North along the bayside to Concord Wharf the Mm unit appears again as an aquifer and is available for use on Occohannock Neck. The salt/fresh interface, however, is present in the bottom of the unit. Therefore, the depth of wells should be limited to an elevation of -200 feet.

FIGURE 15. HYDROGEOLOGIC CROSS–SECTION
CHERITON–MACHIPONGO

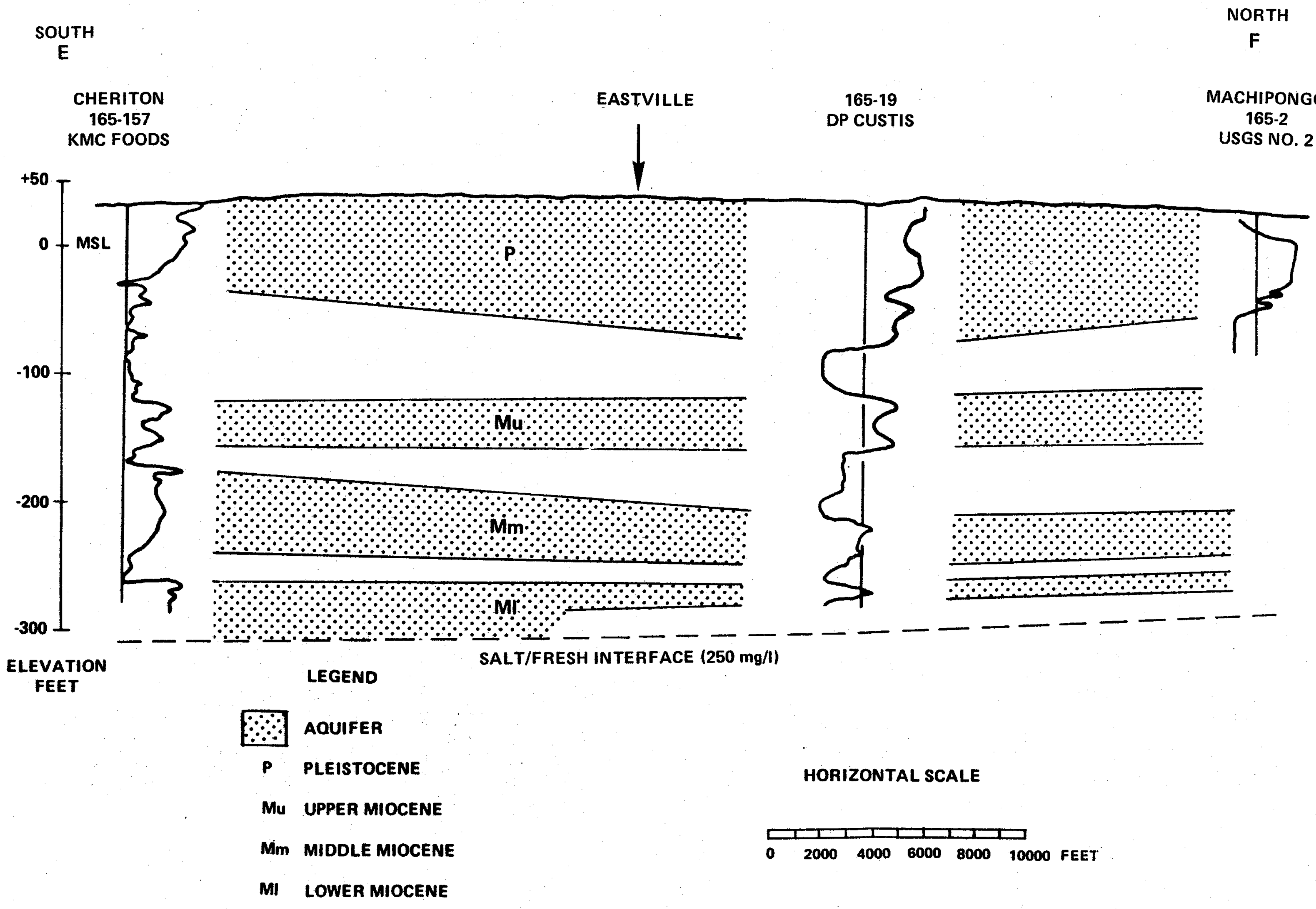


FIGURE 16. HYDROGEOLOGIC CROSS–SECTION
MACHIPONGO–EXMORE

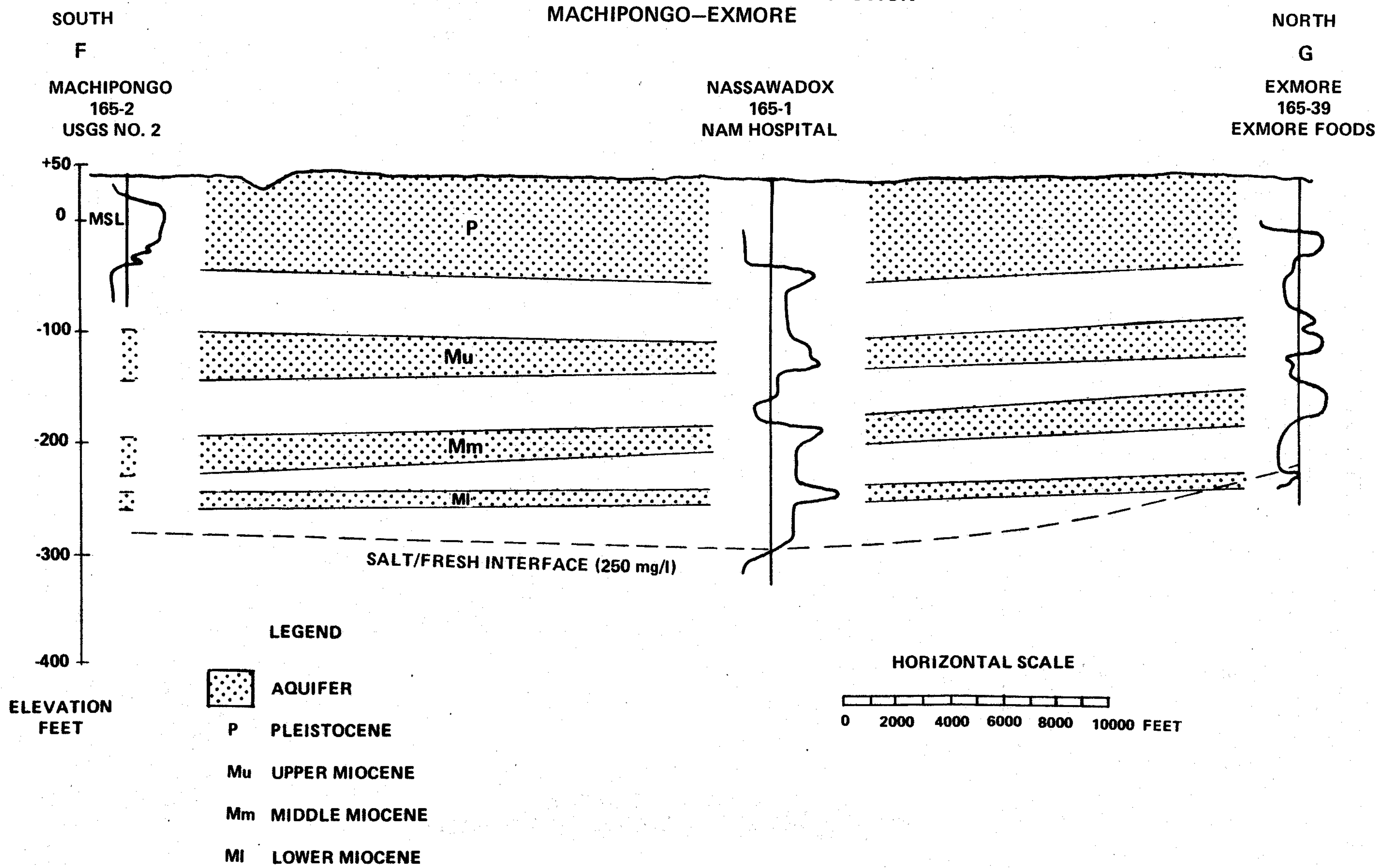
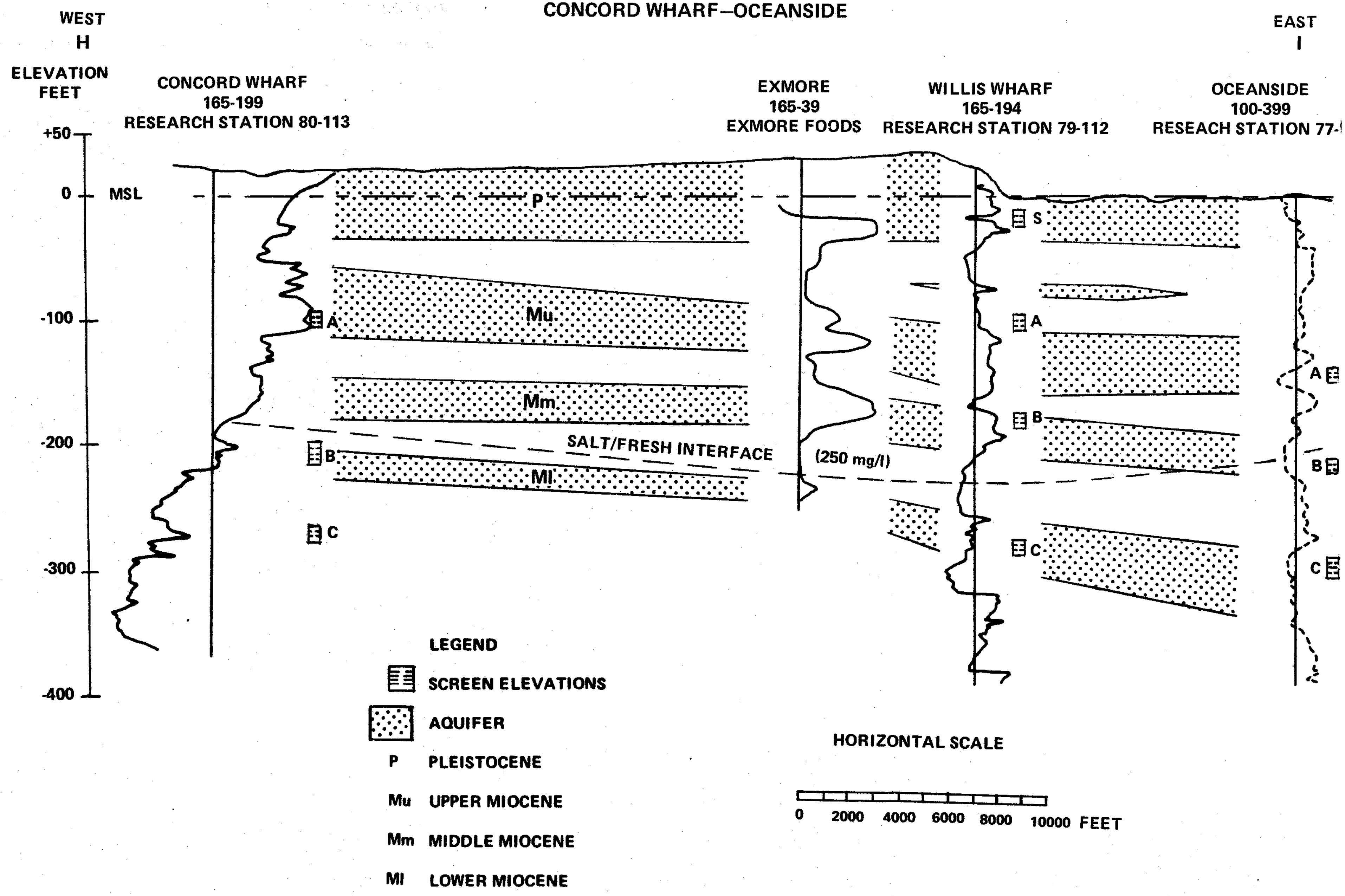


FIGURE 17. HYDROGEOLOGIC CROSS–SECTION
CONCORD WHARF–OCEANSIDE



The major aquifer units along the central ridge are identified on the cross-section shown in Figure 15. The transmissivity of these Miocene aquifers is less than those in the Cheriton area and large yields will generally not be available. The N.A.M. Hospital well in Nassawadox is multi-screened from an elevation of -125 to -266 feet (MSL) and has a total of 60 feet of screen. The yield from this well is 175 gpm with 118 feet of drawdown which in comparison is not as efficient as the wells south of this region. In addition to low yields the Ml unit has the salt/fresh interface located near its upper boundary. Brackish water has been detected at an elevation of -260 feet (MSL). The hydrologic units at the northern boundary of the Eastville/Exmore area are presented in the west-east cross-section shown in Figure 17. In the Exmore area several changes take place over short distances, but in general the hydrologic units can be correlated to the units described earlier. Transmissivity values improve in the north-east portion of the region. The Mm unit is productive and contributes most of the water in the multi-screened wells of Exmore Foods and the Town of Exmore, and the American Original Corporation in Willis Wharf. Total pumpage by these users has averaged approximately 950,000 gpd but is seasonally variable. A pump test was conducted at the Exmore Foods plant. Figure 18 shows a distance drawdown graph developed from the information obtained through the pump test. These values can be used for planning purposes in this region. Pump test data for this pump test are presented in Appendix B.

The salt/fresh water interface has been very well defined along this cross-section. The interface slopes down towards the east, where it was found in the Ml unit at an elevation of -200 feet below Exmore Foods and in the aquitard between the Mm and Ml contact seen in Research Station 79-112.

Farther east, at research station 77-102, the interface occurs at an elevation of -200 feet. The Ml unit in this northern portion of the region, therefore, does not contain potable water and the effective use of the aquifers is restricted to the bottom of the Mm unit. The depth to the interface along the central ridge is at elevation -200 feet MSL and gradually rises in an east-west direction. At Concord Wharf the bottom of the Mu unit (-110 feet MSL) is the effective depth above which potable water can be obtained. The impact on this aquifer has been substantially reduced since the cessation of pumpage from Exmore Foods. Also, records from observation well 79-112B show that although a fluxuation of approximately two feet has been recorded, recovery to normal levels occurs during periods of slack pumpage.

The transmissivity in the area is about 20,000 gpd/ft and the storativity is about 0.0007. These values were obtained from the Exmore pump test. None of the research stations have shown evidence of excessive pumpage or a migration of the salt/fresh water interface.

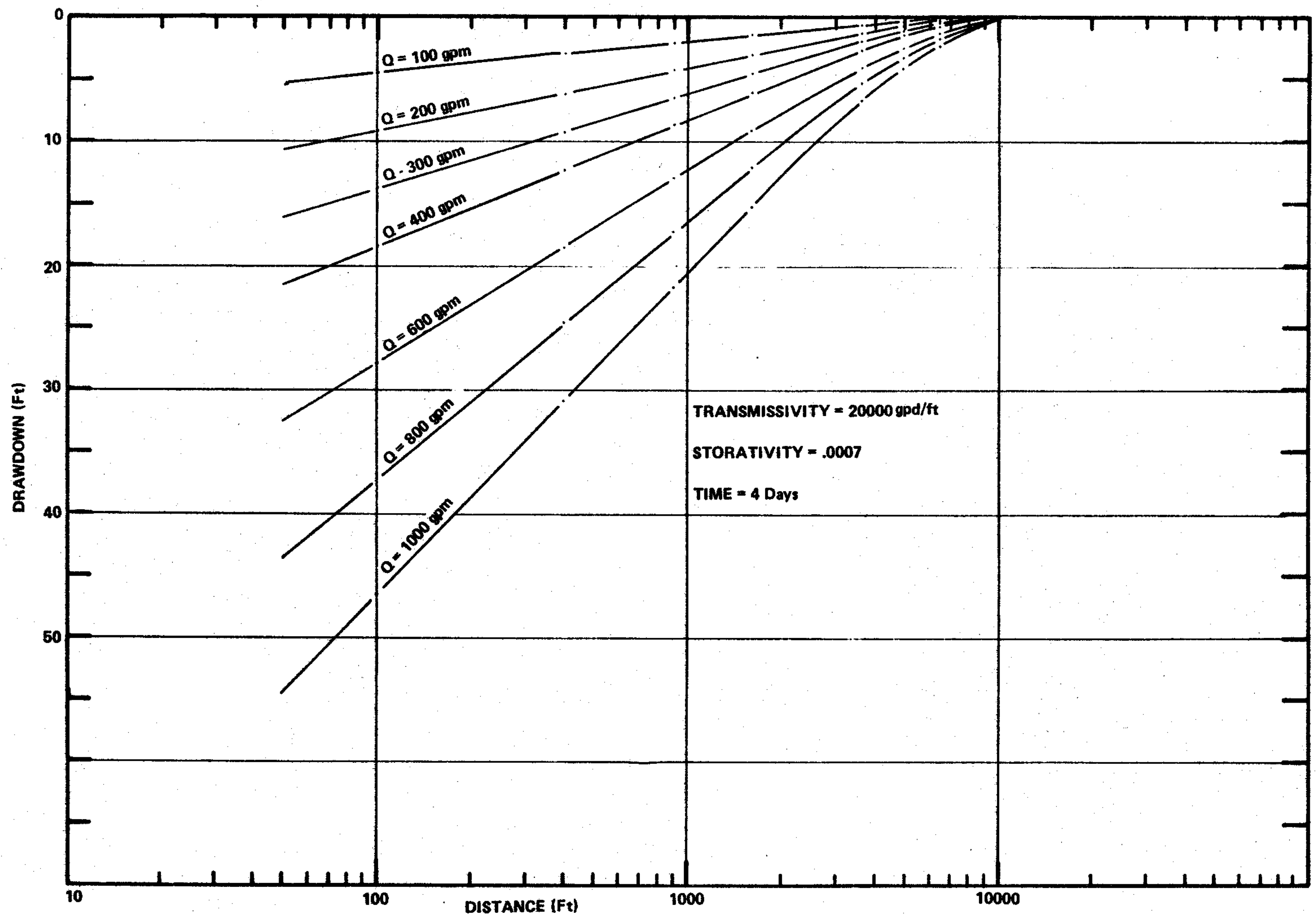


FIGURE 18. DISTANCE–DRAWDOWN GRAPH, EXMORE FOODS

SPECIFIC AREA INFORMATION - EXMORE TO MELFA

The geology (hydrogeology) of this area is shown in two cross-sections, a north-south section along the central ridge (Figure 19) and an east-west section perpendicular to the central ridge (Figure 20). The main aquifer systems, previously described, are present in this area. However, lenses of silt and clay near the Town of Keller divide the upper aquifer into several distinct units at the expense of the water bearing capability of the upper aquifer. The addition of the clay and silt lenses as well as the increased thickness of the upper aquitard to the upper aquifer both contribute to the fact that there is less of the aquifer available for water production. Several distinct changes take place in a east-west direction, but the main aquifer units can be correlated across this section. At Hack's Neck there exists more sand and shell fragments in the upper units but the lower portion of the system is principally silt, as reflected by the E-log of research station 77-106. Towards the central ridge and farther east, the lower and middle units of the Miocene are productive. No major pumpage occurs in this region. Two of the largest wells are located at the Melfa industrial park; they were pump tested at 200 gpm and transmissivity values were found to be between 3000 and 4000 gpd/ft; no observation well was used and therefore storativity could not be calculated. Both of these wells have 50 feet of screen in the Ml unit. Domestic, commercial and agriculture wells account for the major pumpage in this region. No major pumpage is taking place, and no major cones of depression have developed.

SPECIFIC INFORMATION - MELFA TO ACCOMAC

The hydrologic profile of this area is shown in two cross-sections, a north-south section from Melfa to research station 78-109 (Figure 21) and an east-west section from station 78-109 to station 77-101 (Figure 22). The four different aquifers, P, Mu, Mm and Ml can be correlated using the geophysical logs. The Pleistocene unit is relatively thin, less than 60 feet thick and is underlain by a confining bed which ranges in thickness from 60 to 100 feet. This stratum contains lenses of permeable material, which at research station 77-101 and well 100-27 are sufficiently sandy to be used as aquifers. The Mu and Mm unit are separated by a thin aquitard (less than 30 feet thick) over most of the area. Several small, local aquitards are present, but these units are not continuous and generally a good hydraulic connection is maintained between the upper and lower units. The lower unit of the Miocene has some silt lenses but these are also discontinuous. Groundwater withdrawal in this area is primarily by domestic, public and industrial pumpage. The largest industrial withdrawal takes place in this area and amounts to an average of 1.58 MGD. This pumpage by Perdue, a poultry processor, has caused the largest cone of depression on the Eastern Shore, but no evidence has been found that the salt water is moving laterally or vertically towards this cone. Research station

FIGURE 19. HYDROGEOLOGIC CROSS–SECTION
EXMORE – MELFA

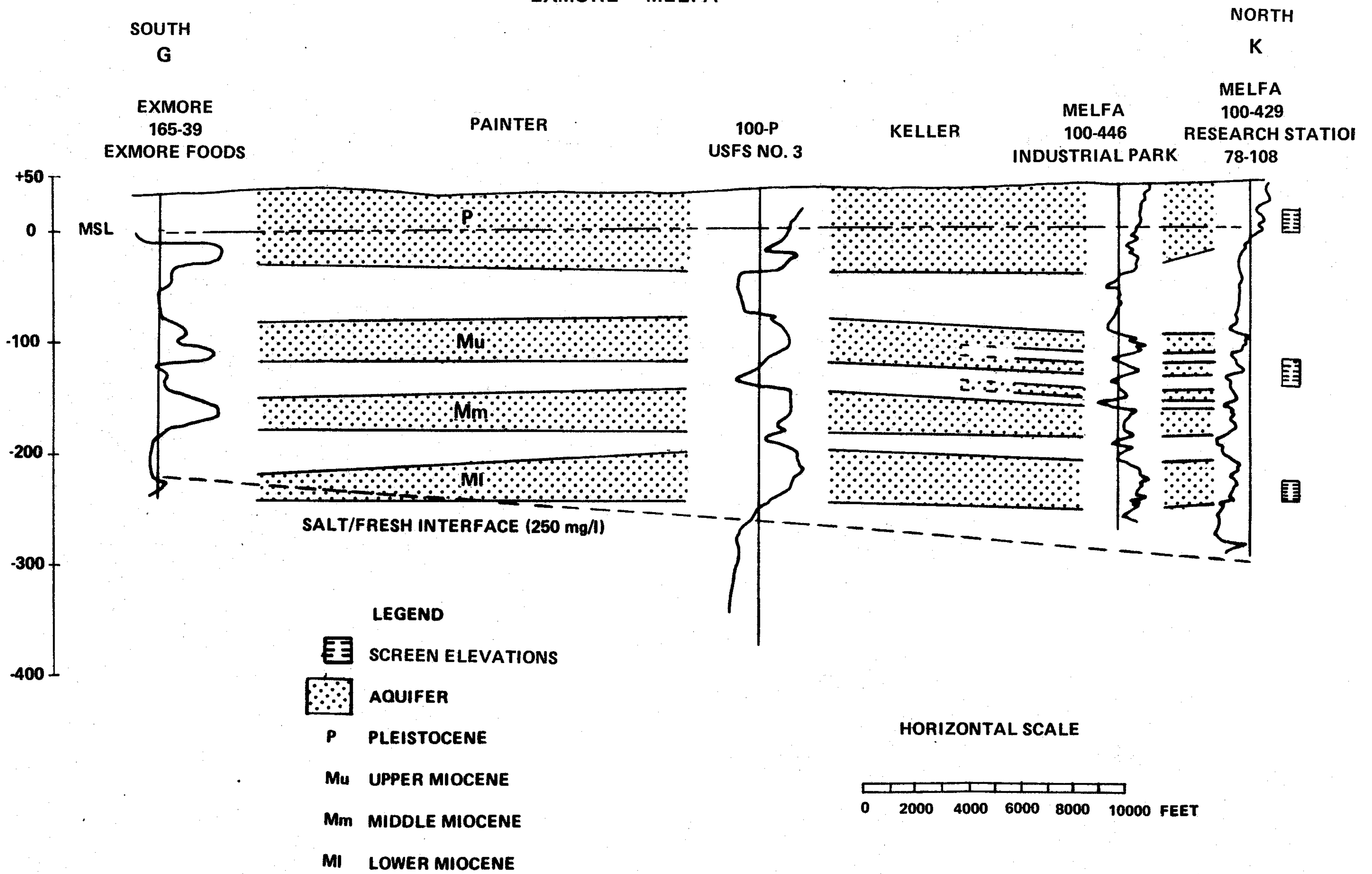


FIGURE 20. HYDROGEOLOGIC CROSS-SECTION
HACK'S NECK – WACHAPREAGUE

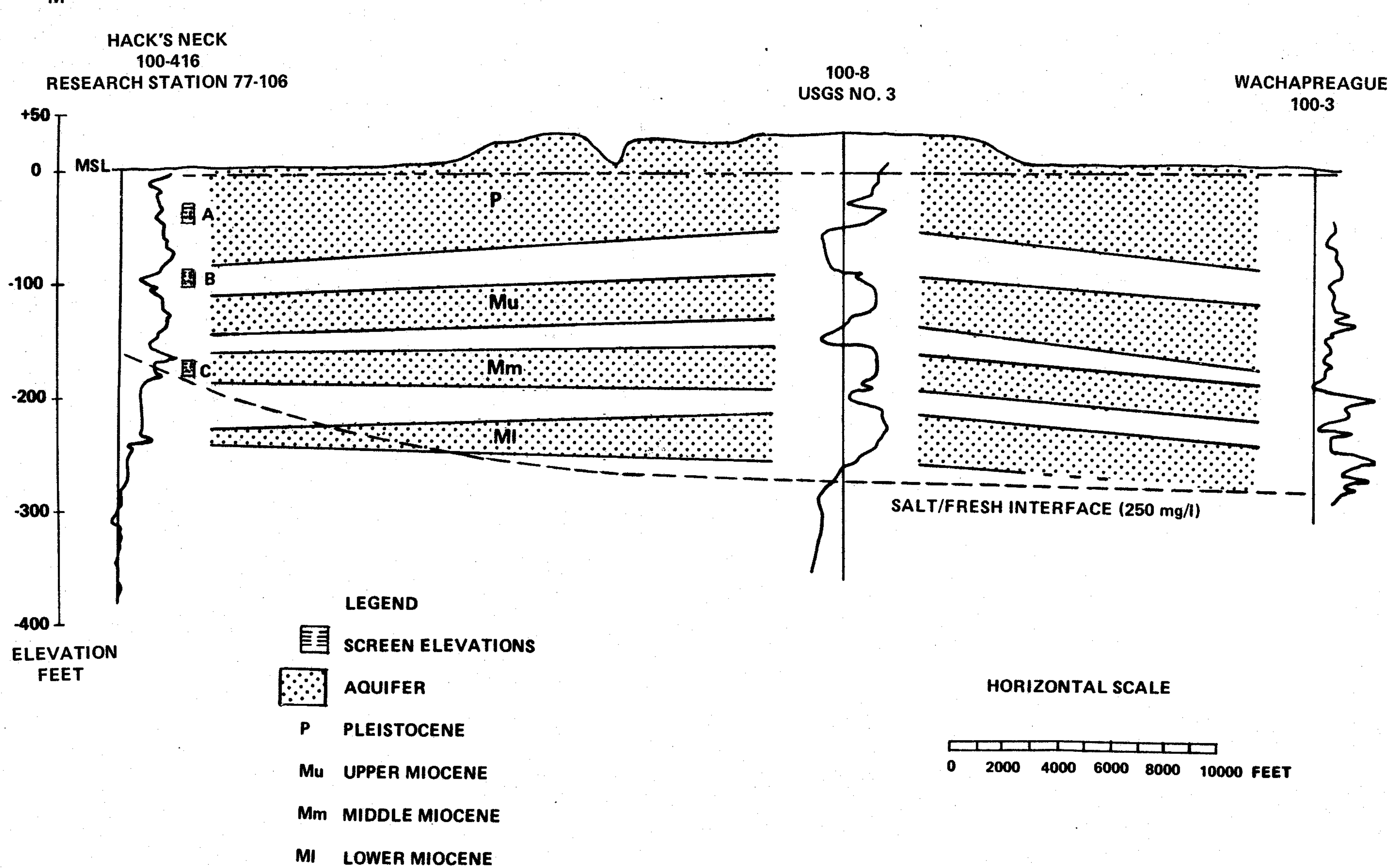


FIGURE 21. HYDROGEOLOGIC CROSS–SECTION
MELFA –BAYSIDE

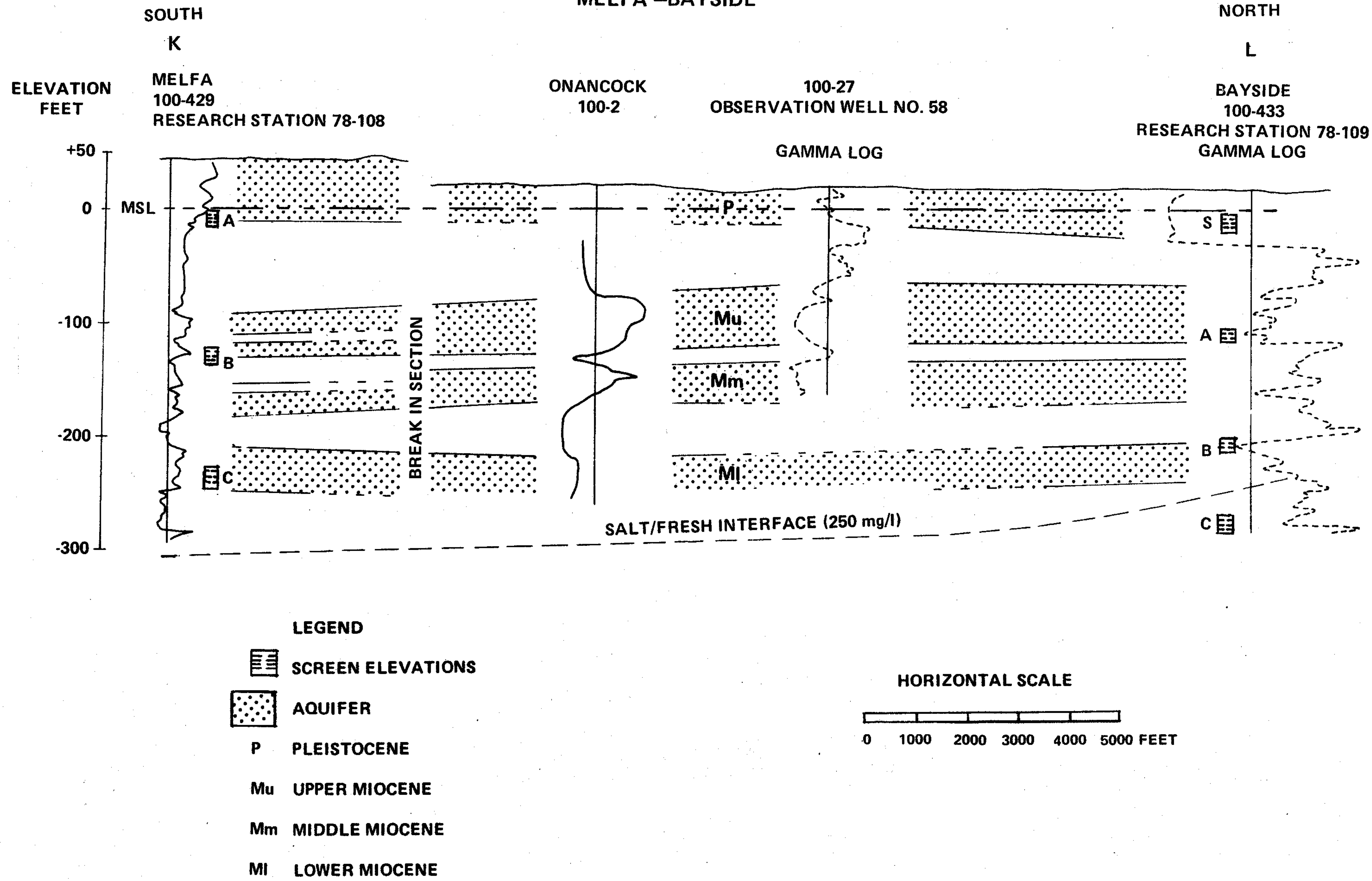
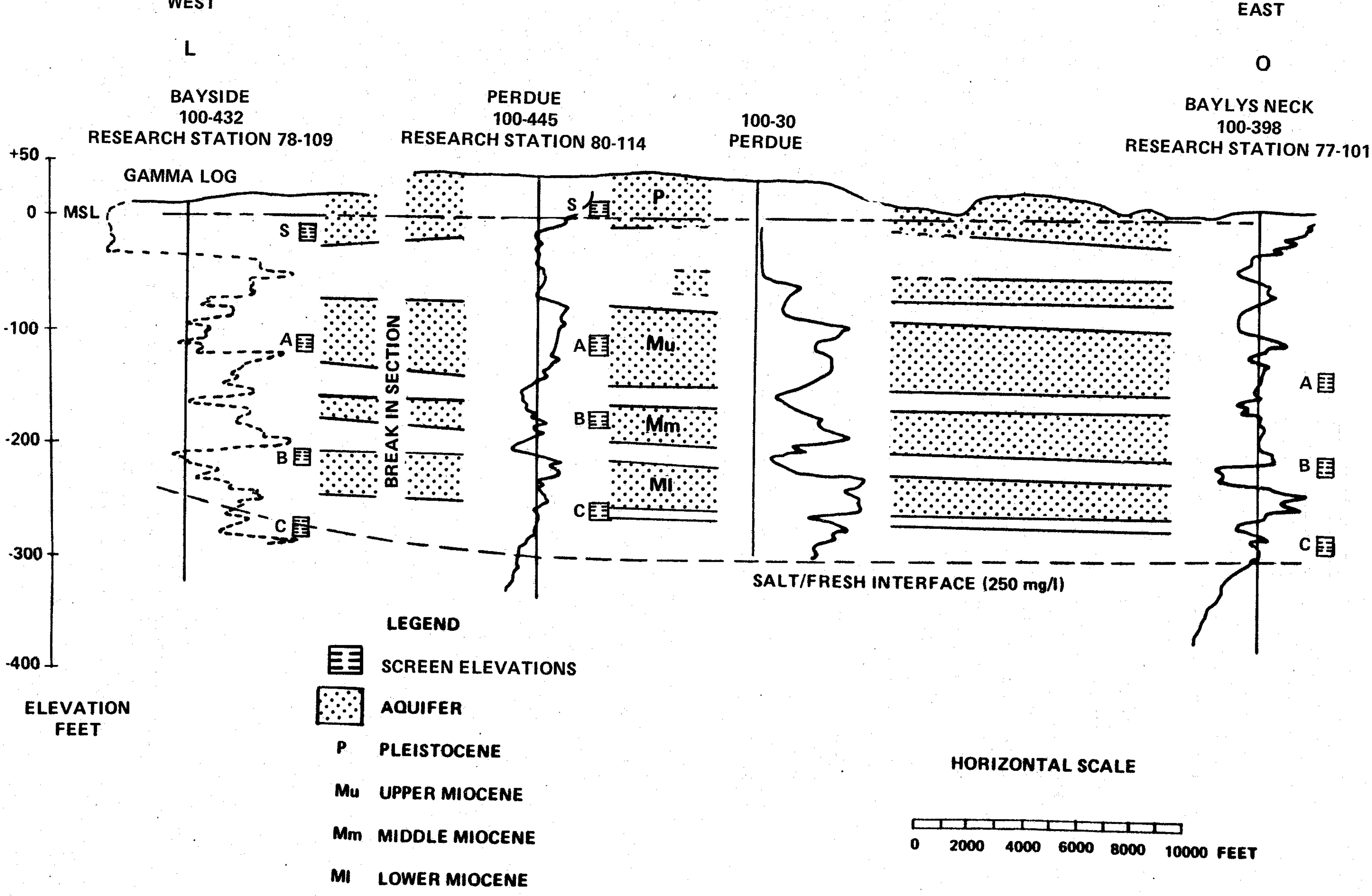


FIGURE 22. HYDROGEOLOGIC CROSS-SECTION
BAYSIDE — BAYLYS NECK



80-114 was drilled early in 1980 so that long term water level and quality data within the cone of influence could be obtained. Water level data indicate that most of the influence caused by the pumpage is in the Ml unit, water levels average -48 feet MSL, while water levels in the Mm and Mu unit are -28 and -5 feet MSL respectively. Because of the water level in the Ml unit, the threat of salt water upconing exists in this unit. No change in salinity has been noticed and it is probable that the interface is at a depth sufficient to sustain the current drawdown. Lateral intrusion of salt water would be expected to occur through the Ml or Mm unit but detrimental effects caused by Perdue's pumpage have not been noticed in the research stations east and west of the plant. The cone in this area, based on the long term water levels from an observation well within 50 feet of Perdue's production well No. 2, is stable near the center. If a long term declining trend of water levels is occuring in this area, it will be noticed by monitoring the water levels in research station 80-114 over a period of years, however, it is likely that a balance of withdrawal versus recharge has been reached.

In addition to the pumpage by Perdue, there is municipal pumpage by the Town of Onancock, averaging 192,000 gpd. Domestic and commercial pumpage is estimated to be less than 200,000 gpd. This latter pumpage is mostly scattered over a wide area and will only have a slight effect on the water levels. In the Town of Accomac, pumpage from the lower unit of the Miocene is influenced by the withdrawals at Perdue and lower water levels occur in wells already placed in this unit.

Although very large withdrawals are made from the aquifers in this region, the replenishment rate due to precipitation, seems to be adequate. A primary unknown is the recharge rate to the Miocene units, and only a long term monitoring record will establish the impact to the units. Due to the variation in water levels in the different aquifers it can be expected that the lateral extent of the cone at Perdue varies depending on which aquifer is measured. Most of the effect of the pumping is expected to be within a mile radius from the well field and no effects have been noticed at research station 77-101 which is 1.8 miles east of the plant.

Outside of this limit, water levels are normal and domestic uses have not been affected. The high transmissivities found at the Perdue Plant are due to high permeabilities of the middle and lower unit of the Miocene. These transmissivity values are expected to continue south and northward. Outside Perdue's cone of influence south of Accomac, adequate quantities of ground water are available.

SPECIFIC AREA INFORMATION - ACCOMAC TO HALLWOOD

Proper evaluation of the geohydrology in this area is difficult because geophysical data are available from only a few wells in the area which are too widely spaced to allow for accurate interpretation of the cross-section. The major units can be correlated across this area and only minor changes in geology were noted to occur. Major pumpage in this area is by the Town of Parksley (92,500 gpd) and Byrd Foods at 68,500 gpd. Byrd Foods is a seasonal operation but can pump over 200,000 gpd during its peak production period. The cones of influence from these two users are not large. Records show that the water levels at Byrd Foods will return to static conditions during the off-season. This area is capable of sustaining additional withdrawals if proper engineering practices are used in the location of well fields.

SPECIFIC AREA INFORMATION - HALLWOOD TO THE MARYLAND BORDER

The geohydrology of this area is represented by two cross-sections; a northwest-southeast section (Figure 23) through research stations 78-110 and 77-107 and a north-south section (Figure 24) from 77-107 to Captain's Cove in the northeast portion of the county. The same Pleistocene unit and the three Miocene units can be identified in this area, although several sub-units occur. The Pleistocene is separated from the upper Miocene unit by an aquitard 20 feet thick which extends over most of the region. However, at station 78-110, there are several distinct alternating layers of silt and sand within the Pleistocene. The upper and middle units of the Miocene are separated by a layer of silt but in many areas this silt layer is not distinctly one unit, but consists of alternating layers of silt and sand. The transition to the lower Miocene can be easily correlated across the area, and is also the unit in which the salt/fresh water interface occurs.

Water withdrawals in this area are in excess of 1.5 MGD, the major portion of which are industrial and public supply withdrawals. Among the larger withdrawals Holly Farms Incorporated pumps an average of 745,000 gpd, the Town of Chincoteague averages 419,000 gpd and the NASA wells pump an average of 166,000 gpd. Small public supply, domestic, and commercial wells are spread out and pumpage from these have an insignificant effect on the aquifer. The pumpage from Holly Farms creates a cone of depression within the Hallwood-Temperanceville area. Observation well data are not available within this cone and therefore the water level drop in each of the aquifers is not known. Research station 77-107 was drilled 1.5 miles southeast from the center of pumpage and no effect from Holly Farms pumpage is detected. It is suspected that the cone of influence is within a one mile radius of the plant, and water levels near the plant probably do not exceed -20 feet MSL. Transmissivity values calculated from a pump test with an observation well are about 20,000 gpd/ft, indicating that a good aquifer exists in this area. Supply wells for the Town of Chincoteague have created a cone of depression. This pumpage takes place on or near the NASA base on the mainland and is piped to the island. The last production well drilled is multi-screened in the upper and middle unit of the Miocene. Additional

FIGURE 23. HYDROGEOLOGIC CROSS–SECTION
WITHAMS – ASSAWOMAN

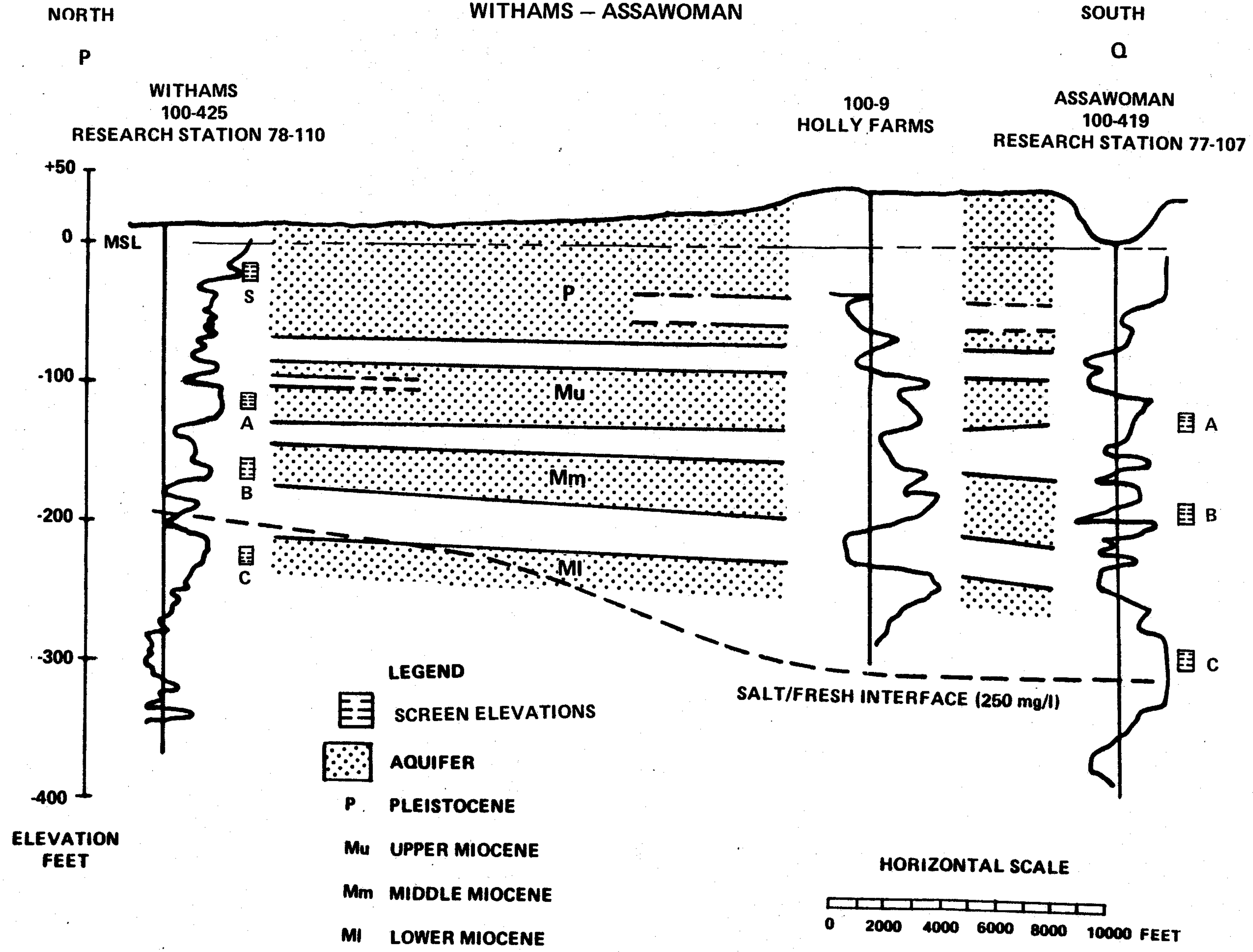
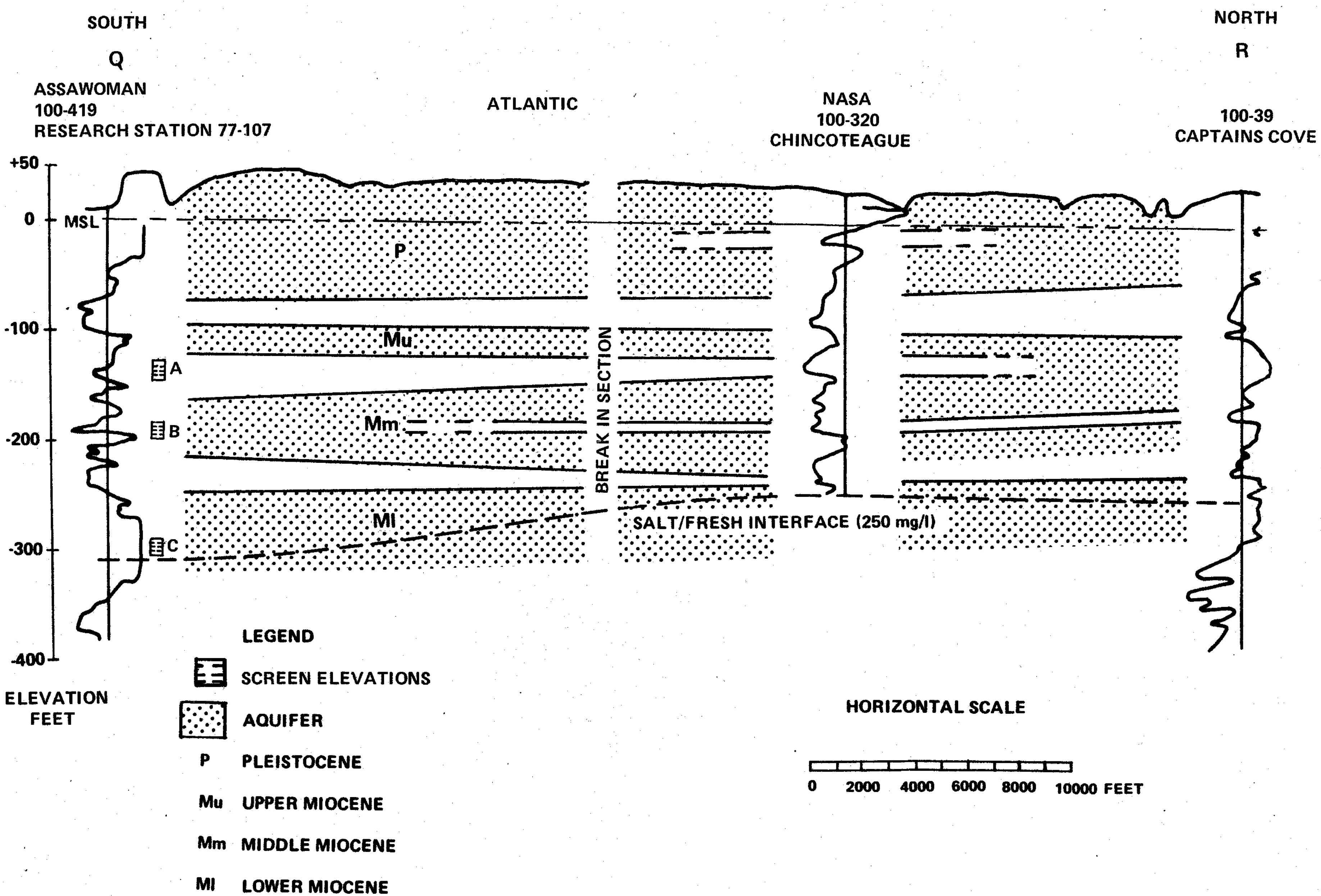


FIGURE 24. HYDROGEOLOGIC CROSS–SECTION
ASSAWOMAN – CAPTAIN COVE



pumpage is from the lower unit, where most of the effect from the withdrawals takes place. A pump test was conducted using the most productive well and using a recently drilled research station and other wells as observation wells. A transmissivity and storativity of 8400 gpd/ft and .0002, respectively were used to construct a distance-drawdown graph (Figure 25). This graph can be used for planning purposes in the northern area of Accomack County. Additional information on the pump test is presented in Appendix C.

Outside the two cones of depression adequate quantities of water are available. It is estimated that withdrawals up to 500,000 gpd, using proper well design, can be made along and east of the central ridge, providing a sufficient distance from the salt/fresh water interface is maintained. West of the central ridge the salt/fresh water interface is found at a higher elevation and much of the lower unit of the Miocene is not usable. This conclusion is indicated by the deepest observation well at research station 78-110, where the chloride content at -230 feet MSL was found to be 126 mg/l, indicating that this well is close to the interface.

RESEARCH STATION INFORMATION

The following pages contain brief descriptions of each research station and present the chemical and physical data which are accumulated at each station. Stations are identified by a research station number and a name. Wells are identified by a SWCB number and the research station number with S, A, B or C added. Well S is the driller supply well and the shallowest (generally located in the Pleistocene) wells, this well was drilled only at the stations where no immediate water supply was available, A, B, and C follow in descending order of depth. The well depth was located using the geological and geophysical logs, available area information and the probable location of the salt/fresh interface. Water levels are measured by tape unless a continuous water level recorder is used, daily readings are obtained from these units. During the pumping of the wells, water level measurements were taken, these pump tests were very limited in time and rate and the data can be viewed only as an indication of the relative performance from each aquifer at the particular station. Figure 26 shows the locations of the research stations.

RESEARCH STATION 77-101

Baylys Neck

This station is located approximately 1.8 miles east of Perdue Foods in Accomack County. Three wells were installed at this location and have the following screen depths:

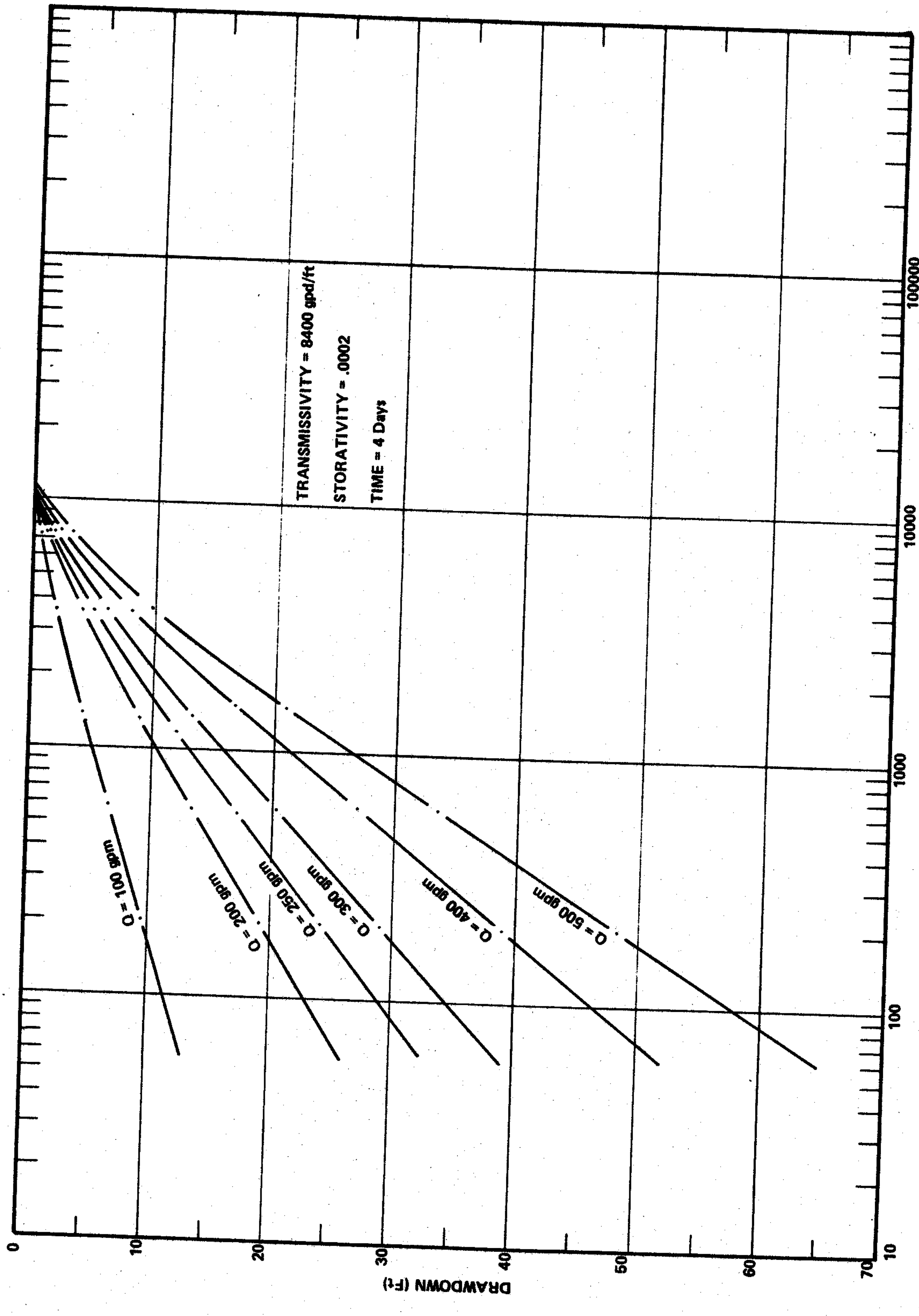
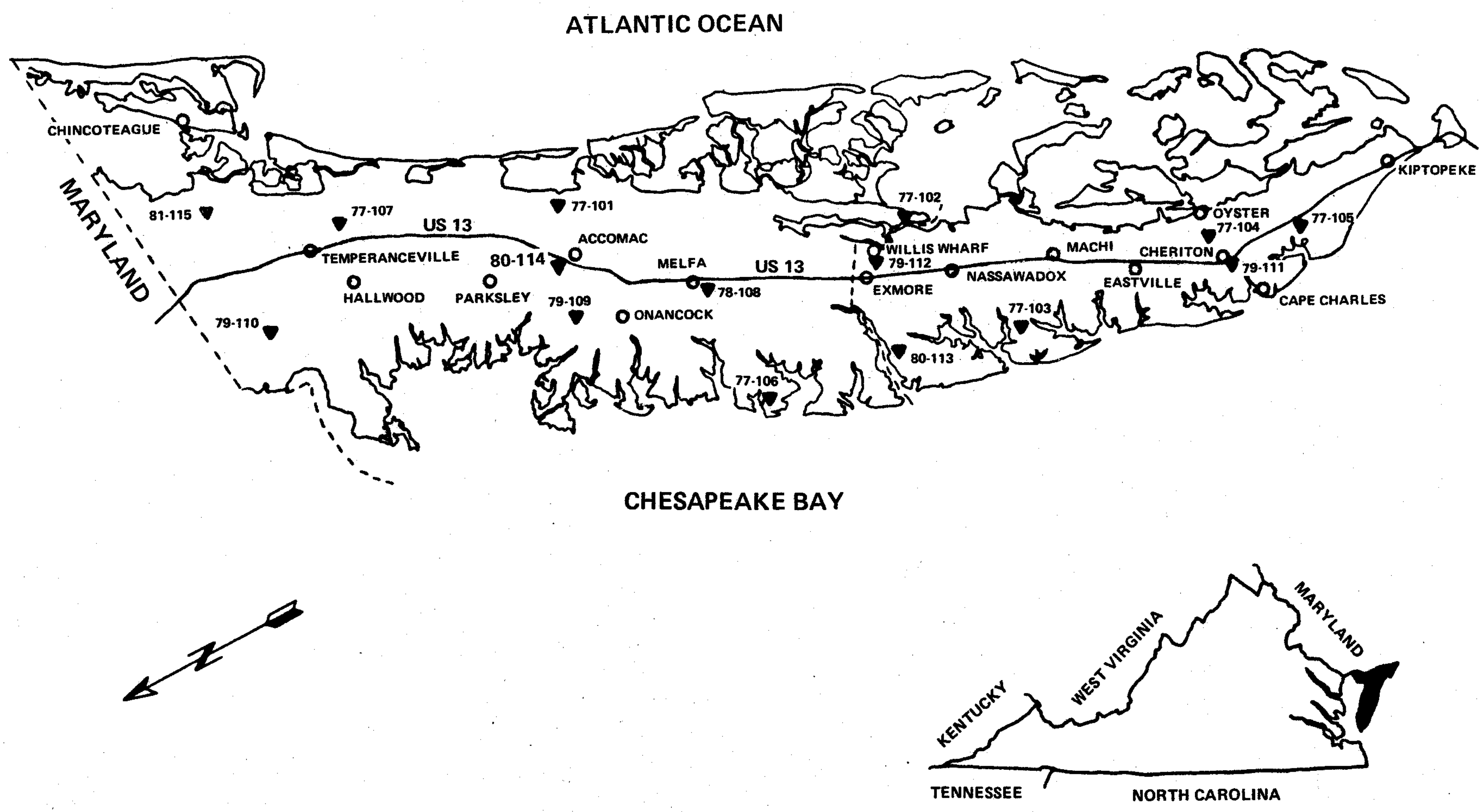


FIGURE 25. DISTANCE–DRAWDOWN GRAPH, TOWN OF CHINCOTEAGUE

FIGURE 26. RESEARCH STATION LOCATIONS EASTERN SHORE OF VIRGINIA



Well	SWCB No.	Screen Elevation MSL (Ft)
A	100-396	-134 to -144
B	100-397	-202 to -212
C	100-398	-274 to -284

Water levels for all three wells have been recorded since June, 1977. At the end of 1979, the data showed that the levels in all three wells has risen an average of 1.5 feet. Wells A and B have similar water levels, and showed seasonal fluctuations ranging from +4.2 and +5.5 feet MSL in 1979. The highest level occurs during May and the lowest in October. Because the data show much similarity between wells A and B it is interpreted that there is much leakage between the two units. Well C on the other hand is separated from Well B by a more impervious aquitard than the layer between Well A and B. The water level in Well C is five feet lower than in the other two wells. A water level recorder was placed on Well C in 1978. The data from the recorder show small daily fluctuations which are attributable to the tidal cycles. The fluxuation in levels range from .1 to .4 feet.

The three wells were pumped in 1977 and again in 1979. Quality samples were taken and analyzed by Consolidated Laboratory in Richmond. Well C contained chloride levels of 129 mg/l in 1977 and only 8 mg/l in 1979. The decrease in these chloride levels relates to the increase of the water levels between the same period and thus indicates an outward movement of the salt/fresh interface. Table shows chemical data from all three wells.

During pumping in 1979 drawdown measurements were taken with a constant discharge of 8 gpm. Wells B and C had drawdowns of 16.1 and 14.7 feet respectively, while Well A measured 32.1 feet. Although the yield is too low to make meaningful estimates of the transmissivity of the aquifer units, these values do provide a relative indication of the productivity of the units since the research station wells are constructed equivalent.

RESEARCH STATION 77-102

Oceanside

This station is located in southeast Accomack County, approximately three miles east of the Town of Exmore. Three wells were installed at this location with the following screen depths:

Well	SWCB No.	Elevation (MSL, Ft.)
A	100-401	-137.5 to -147.5
B	100-400	-203.5 to -213.5
C	100-399	-289.5 to -299.5

TABLE 4. GROUND WATER QUALITY OF RESEARCH STATION 77-101

WELL	A		B		C	
DEPTH (MSL, Ft)	-144		-212		-284	
Date	6/77	10/79	6/77	10/79	6/79	10/79
pH	7.8	7.9	7.7	7.9	8.0	8.0
Alk./Acid. (as $CaCO_3$)	105	107	110	114	153	118
Total Solids	134	162	167	164	383	168
Chloride	8	7	16	7	129	8
Hardness, EDTA (as $CaCO_3$)	102	100	110	106	131	98
Nitrogen (TKN)	0.2	0.2	0.4	0.5	0.8	0.4
Total Phosphorus	0.1-	0.1-	0.1-	0.2	0.1-	0.1-
Nitrate (as N)	0.08	0.04-	0.36	0.04-	0.23	0.04-
Sulphate		2		2		2
Total Org. Carbon	5	4	6	5	9	5
Fluoride	0.16	0.01-	0.18	0.1-	0.24	0.1-
Calcium	27	32	32	26	42	24
Iron	0.1-	0.29	0.9	.16	0.1	0.08
Magnesium	9	8.1	12	9.6	18	9.8
Manganese	0.02	0.03	0.03	.02	0.02	0.01
Sodium	7	11	9	11	105	13
Potassium	7	5.2	10	8.6	17	9.2
Conductivity		235		259		250

All parameters in mg/l except pH and conductivity (micro-mhos/cm)

The three wells have a full year of continuous water level record; Well B is still being monitored with a recorder. Water levels, recorded since June 1977, have shown no specific trend except for seasonal fluctuations, which are 4.5 feet in both Well A and B and 3 feet in Well C. Levels range from +2.5 and -2.5 feet (MSL) in Wells A and B and +2.5 and -0.8 feet (MSL) in Well C. Tidal fluctuations occur in all three wells with some variation seen in each well; Well A varies 1.9 to 2.4 feet, Well B .5 to 1.3 feet and Well C .5 to .8 feet.

Quality samples were taken and analyzed in 1977 and in 1979. The water from Well A is somewhat alkaline and moderately hard. Chemical analyses from Wells B and C are both high in chloride values. (See Table 5 for Chemical data).

Drawdown measurements were obtained from the wells during the quality testing in 1979. Wells A and C are similar with 13.5 and 15.5 feet of drawdown respectively. Well B had a drawdown of only 2 feet. The wells were pumped at a rate of 11 gpm.

RESEARCH STATION 77-103

P. C. Kellam

This station is located in central Northampton County, approximately three miles west of Birdnest. Three observation wells were drilled at this location and they have the following screen depths.

Well	SWCB No.	Elevation (MSL, Ft)
A	165-144	-12 to -22
B	165-145	-107 to -117
C	165-146	-210 to -220

Water levels have been recorded since October, 1977. All three wells experienced a rise in levels during the period from 1977 to 1979. Well A rose an average of 6 feet, Well B 3 feet and Well C an average of 1 foot. The highest water level is in Well A, during 1979 it had a seasonal range from 10 to 13 feet, Well B ranged from 5.5 to 7.3 feet and Well C ranged from 3.77 to 4.8 feet (MSL). A continuous recorder placed on Well B had indicated that there is no tidal effect.

These wells were pumped in 1977 and in 1979. Well A is a water table well with high total dissolved solids and with very hard water. Both nitrate (17.8 mg/l) and sulphate (180 mg/l) were the highest found of all the research stations. Well C contains high chlorides; in 1977 a value of 297 mg/l was found, in 1979 some reduction was evident to 244 mg/l, possibly due to the rise in water levels.

The wells were measured for drawdown while pumping at a constant rate of 11 gpm. The drawdown for Well A, B and C were 13.5, 43.5 and 16 feet respectively.

TABLE 5. GROUND WATER QUALITY OF RESEARCH STATION 77-102

WELL	A		B		C	
DEPTH (MSL, Ft)	-147.5		-213.5		-299.5	
Date	6/77	5/79	6/77	5/79	6/77	5/79
pH	7.7	8.2	7.9	8.3	8.0	8.2
Alk./Acid. (as $CaCO_3$)	133	193	259	266	361	378
Total Solids	314	349	768	866	3830	3976
Chloride	52	49	350	333	2217	2147
Hardness, EDTA (as $CaCO_3$)	91	90	105	102	357	376
Nitrogen (TKN)	2.6	2.8	3.8	3.8	7.8	7.7
Total Phosphorus	0.3	0.3	0.1	0.2	0.1	0.2
Nitrate (as N)	0.04-	0.04-	0.04-	0.04-	0.04-	0.04-
Sulphate		1-		1		1
Total Org. Carbon	10	7	10	35	12	3
Fluoride	0.18	0.13	0.36	0.32	0.79	0.68
Calcium	17	17	16	13	56	36
Iron	0.6	0.4	0.1	0.3	0.6	0.5
Magnesium	15	12.4	21	15.1	73	6.3
Manganese	0.06	0.06	0.01	0.04	0.02	0.01-
Sodium	78	55	303	220	1547	512
Potassium	29	19	34	19	71	47
Conductivity	460		1335	1579	5933	

All parameters in mg/l except pH and Conductivity (micro-mhos/cm)

TABLE 6. GROUND WATER QUALITY OF RESEARCH STATION 77-103

WELL DEPTH (MSL, Ft) Date	A -22 9/77	 5/79	B -117 9/77	 5/79	C -220 9/79	 5/79
pH	6.1	6.8	7.7	7.9	8.3	8.4
Alk./Acid. (as $CaCO_3$)	12	25	93	80	359	352
Total Solids	445	508	227	221	945	877
Chloride	43	30	24	24	297	244
Hardness, EDTA (as $CaCO_3$)	224	229	116	141	46	57
Nitrogen (TKN)	0.1	0.4	0.2	0.1-	1.4	1.3
Total Phosphorus	0.1-	0.1	0.1-	0.1	0.1	0.2
Nitrate (as N)	12.0	17.5	0.26	0.49	0.6	0.04-
Sulphate	113	246	40	394	12	44
Total Org. Carbon	1	4	5	3	15	9
Fluoride	0.13	0.10-	0.20	0.10-	1.12	1.08
Calcium	45	62	37	39	9	8
Iron	1.0	0.16	0.2	0.04	0.1	0.06
Magnesium	29	18	7	5	8	6
Manganese	0.03	0.06	0.04	0.11	0.01-	0.01-
Sodium	23	8	30	12	393	275
Potassium	4	8	5	1	17	14
Conductivity						

All parameters in mg/l except pH and Conductivity (micro-mhos/cm)

RESEARCH STATION 77-104

Doughty's Grocery

This station was drilled one and a half miles east of the Town of Cheriton. Four wells were drilled at this location and they have the following screen depths:

Well	SWCB No	Elevation (MSL, Ft)
S	165-156	+2 to -8
A	165-147	-102 to -112
B	165-148	-202 to -212
C	165-149	-272 to -282

The water levels in these wells have been recorded since October, 1977 and range from a high of 15.4 feet in Well S to a low of 4.1 feet (MSL) in Well C. Variation of water levels in Well S is about one foot, Well A ranges from 8.3 to 13.6 feet and Well B from 7.5 to 14 feet (MSL). Well C has a range from 4.1 to 10 feet (MSL). Tidal effects are very small, a maximum of 0.2 feet has been observed in the data from the water level recorder on Well A.

Quality samples (Table 7) were obtained in 1977 and in 1979, except in Well S, the capacity of the pump was too large and caused the well to be pumped down to the screen. Although a rising trend in the water levels was not noticed in any of the wells, a drop in chloride content was observed between 1977 and 1979. Considering the anomaly present in Well A in the sample from 1977 and the drilling record, it is probable that the formation was contaminated during drilling of the pilot hole in 1977 by the drilling water, which was brackish.

Drawdown measurements were obtained during sampling. Well S was pumped dry at 8 gpm. Well A is very productive, a drawdown of one foot was observed, Well B and Well C had drawdowns of 14 and 17 feet respectively. All wells were pumped at a rate of 8 gpm.

RESEARCH STATION 77-105

Cape Center

This station is located 0.5 miles northwest of Cape Center, Northampton County. It consists of three wells with the following screen locations:

Well	SWCB No.	Elevation (MSL, Ft)
A	165-159	-90 to -100
B	165-160	-156 to -166
C	165-161	-245 to -255

TABLE 7. GROUND WATER QUALITY OF RESEARCH STATION 77-104

WELL	S	A		B		C	
DEPTH (MSL, Ft)	-8	-112		-212		-282	
Date	9/77	9/77	9/79	9/77	9/79	9/77	9/79
pH	7.0	7.5	7.9	7.6	7.8	7.9	7.8
Alk./Acid. (as $CaCO_3$)	23	97	99	96	100	104	104
Total Solids	1799	266	192	169	164	976	685
Chloride	66	155	31	72	31	903	293
Hardness, EDTA (as $CaCO_3$)	150	135	103	99	91	210	176
Nitrogen (TKN)	0.3	0.2	0.3	0.1	0.3	0.3	0.4
Total Phosphorus	0.1	0.2	0.2	0.1-	0.1-	0.1-	0.1-
Nitrate (as N)	6.1	0.04-	0.01-	0.04-	0.04-	0.04-	0.04-
Sulphate	67	7	2	5	2	51	34
Total Org. Carbon	54	3	4	4	6	3	6
Fluoride	0.23	0.11	0.1-	0.19	0.15	0.32	0.19
Calcium	59	44	42	23		30	43
Iron	6.4	0.3	0.2	0.3		1.0	0.23
Magnesium	9	4	3.8	10		29	30
Manganese	0.36	0.1	0.08	0.01		0.05	0.04
Sodium	11	46	30	27		296	208
Potassium	3	2	1.9	7		14	15
Conductivity							

All parameters in mg/l except pH and Conductivity (micro-mhos/cm)

The water level difference between Wells A and B is less than 0.5 feet with a normal seasonal range of 11.4 and 14.2 feet (MSL). The level in Well C is several feet lower with a range from 5.0 to 6.1 feet. Water levels have been recorded by tape since June, 1978 and a short term record by a continuous recorder is available for Well A. Only the longer seasonal changes in water levels were noticed and no tidal effects were recorded.

Water quality analysis was obtained in 1978 and again in 1980. The hardness of the water in Well B was 34 mg/l which is a comparatively soft water value for this aquifer. The actual 1978 chloride values for Well B and C (1 mg/l) were probably higher than the laboratory values indicate, and should be close to the 1980 values. (See Table 8).

Drawdown measurements for these wells indicated Well C as the most productive with 13.8 feet of drawdown. Well A and B had values of 14.7 and 66.8 feet drawdown respectively. All wells were pumped at a steady 8 gpm.

RESEARCH STATION 77-106

Hack's Neck

This station is located on the bayside, three miles west of Pungoteague, Accomack County. Three wells were installed at this location with the following screen depths:

Well	SWCB No.	Elevation (MSL, Ft)
A	100-414	-24 to -34
B	100-415	-82 to -92
C	100-416	-163 to -173

Water levels have been measured since October, 1977. Strong tidal influences are noted in all three wells, with water levels generally close to the surface. Fluctuations in the three wells range from 1.3 to 3.6 feet.

Water quality samples were taken in 1977 and in 1980. Data from 1977 indicated high chloride values in Wells A and C. The high 1977 value in Well A (178 mg/l) is attributable to the occasional tidal flooding which occurs in the area and the insufficient flushing subsequently. Well C is slightly below the salt/fresh interface with a 1977 value of 313 mg/l. (See Table 9).

Well A is the most productive well, drawdown was 3 feet. Well B and C had drawdowns of 24.8 and 11.3 feet respectively.

TABLE 8. GROUND WATER QUALITY OF RESEARCH STATION 77-105

WELL	A		B		C	
DEPTH (MSL, Ft)	-100		-166		-255	
Date	6/78	8/80	6/78	8/80	6/78	8/80
pH	7.7	7.4	8.0	7.9	8.4	8.3
Alk./Acid. (as $CaCO_3$)	69	67	132	130	368	319
Total Solids	218	228	193	197	594	523
Chloride	20	25	1	13	1	75
Hardness, EDTA (as $CaCO_3$)	122	138	34	42	24	26
Nitrogen (TKN)	0.1-	0.1-	0.1-	0.2	0.5	0.6
Total Phosphorus	0.1-	0.1-	0.1-	0.2	0.2	0.3
Nitrate (as N)	0.07	0.04-	0.01-	0.04-	0.01-	0.04-
Sulphate	66	64	11	9	8	18
Total Org. Carbon	6	4	11	7	16	13
Fluoride	0.01-	0.01-	0.31	0.25	1.58	1 09
Calcium		53		15		10
Iron		0.26		0.14		0.1
Magnesium		2		1.9		3
Manganese		0.03		0.01-		0.01-
Sodium		15		51		179
Potassium		1.2		3.8		9
Conductivity		356	317	328	1003	880

All parameters in mg/l except pH and conductivity (micro-mhos/cm)

TABLE 9. GROUND WATER QUALITY OF RESEARCH STATION 77-106

WELL	A		B		C	
DEPTH (MSL, Ft)	-34		-92		-173	
Date	9/77	8/80	9/77	8/80	9/77	8/80
pH	6.8	6.2	7.9	7.4	7.9	7.8
Alk./Acid. (as $CaCO_3$)	52	66	196	201	229	246
Total Solids	489		294		820	
Chloride	178	92	33	41	313	318
Hardness, EDTA (as $CaCO_3$)	123	78	204	202	185	162
Nitrogen (TKN)	0.4	0.3	0.4	0.4	2.2	2.0
Total Phosphorus	0.4	0.1	0.3	0.2	0.1-	0.1-
Nitrate (as N)	0.04-	0.04-	0.04-	0.04-	0.04-	0.04-
Sulphate	3	9.6	3	1.2	20	17
Total Org. Carbon	6	6	8	11	9	9
Fluoride	0.12	0.1-	0.2	0.12	0.29	0.21
Calcium	23		76	66	60	36
Iron	21		2.8	2.7	1.0	0.18
Magnesium	13		9	7.8	25	47.7
Manganese	0.42		0.07	0.06	0.03	0.02
Sodium	94		28	23	300	200
Potassium	2		5	4.7	20	17
Conductivity		476		562		1549

All parameters in mg/l except pH and conductivity (micro-mhos/cm)

RESEARCH STATION 77-107

Chessir Bros.

This station is located three quarters of a mile southwest of the Town of Assawoman in Accomack County. Three wells were drilled at this location and have the following screen depths:

Well	SWCB No.	Elevation (MSL, Ft)
A	100-417	-120 to -130
B	100-418	-186 to -196
C	100-419	-290 to -300

Water levels have been recorded since October 1977, Well A and B are similar with little difference between them, levels range from 5.5 to 8.9 feet (MSL). No tidal effect was observed in recorder data from Well B. Well C has water levels about 2 feet lower than Wells A and B with a seasonal range of 3.8 to 6.0 feet (MSL).

Quality samples were obtained in 1977 and 1979. Moderately hard water was found in Well B and C. Values for Well A showed it to be in the normal range for the Eastern Shore. The salt/fresh interface was not encountered, and is estimated to be an additional 20 feet below Well C. (See Table 10).

Drawdown measurements were taken during the 1979 sampling. Pumping was held constant at 8 gpm. Well A had a drawdown of 22.5 feet and Well B was 9.5 feet. Well C had a continuous drawdown at the 8 gpm pumping rate, the pump was shut off, when the water level reached the submersible pump.

RESEARCH STATION 78-108

Melfa

This research station is located one mile northwest of the Town of Melfa, Accomack County. Three wells were drilled at this location with the following screen depths:

Well	SWCB No.	Elevations (MSL, Ft)
A	100-427	+7 to -3
B	100-428	-123 to -133
C	100-429	-227 to -237

Water levels have been measured since September, 1978. An average rise of two feet was observed between 1978 and 1979. Seasonal fluctuations range from 1 to 2.1 feet. The water level in Well A ranges from 39.5 to 42.8 feet (MSL). Well B has water levels which range from 32.3 to 36.0 feet and Well C fluctuates from 24.0 to 29.4 feet (MSL).

TABLE 10. GROUND WATER QUALITY OF RESEARCH STATION 77-107

WELL	A		B		C	
DEPTH (MSL, Ft)	-130		-196		-300	
Date	9/77	10/79	9/77	10/79	9/77	10/79
pH	7.2	7.0	8.0	7.9	8.7	7.7
Alk./Acid. (as $CaCO_3$)	52	68	106	162	95	102
Total Solids	100		150	212	212	153
Chloride	7	9	9	17	16	10
Hardness, EDTA (as $CaCO_3$)	62	72	116	114	132	90
Nitrogen (TKN)	0.1	0.2	0.1	0.2		0.2
Total Phosphorus	0.1	0.5	0.1-	0.2		0.2
Nitrate (as N)	0.04-	0.04-	0.04-	0.04-	0.24	0.04-
Sulphate			3	3	8	2
Total Org. Carbon	5	4	6	10	3	5
Fluoride	0.16	3	0.19	0.01-	0.11	0.12
Calcium	12	11	27	19		24
Iron	5.8	1.5	0.2	.07		0.18
Magnesium	4	4.1	8	4.8		10.6
Manganese	0.24	0.08	0.02	0.01		0.03
Sodium	9	11	9	12		21
Potassium	3	3.6	6	26		9.1
Conductivity		160		351	305	223

All parameters in mg/l except pH and conductivity (micro-mhos/cm)

Quality samples were obtained in 1978 and in 1980. Well A was also pumped in 1979. The salt/fresh interface is deeper than Well C, which has a chloride value of 39 mg/l (1978). (See Table 11).

Drawdown measurements in Well A were only 2.8 feet, Well B had 14.3 feet of drawdown and Well C 50.9 feet. Pumping was at 8 gpm. These levels would again indicate that Well A is the more productive well.

RESEARCH STATION 78-109

Bayside

This station is located three miles west of Accomac. Four wells were drilled at this location and have the following screen locations:

Well	SWCB No.	Elevation (MSL, Ft)
S	100-430	-8 to -18
A	100-431	-108 to -118
B	100-432	-206 to -216
C	100-433	-268 to -278

Water level data has been obtained since June, 1978. Levels in Well S fluctuate seasonally from 5.4 to 10.5 feet (MSL), Well A from 4.5 to 7.5 feet, Well B from -1.0 to 1.6 feet and Well C varies from -4.2 to -2.1 feet (MSL). The data indicates that water levels have increased slightly since 1978.

Quality samples were taken in 1978 and in 1980. Well A was also pumped in 1979. The values for the chlorides for Well A, B and C in 1978 are not correct, higher values should have been obtained. These values are suspect because of the total solids, sodium and conductivity values. (See Table 12).

In pumping these wells, both Well A and C performed poorly, with drawdowns in excess of 100 feet, Well B had 11.5 feet and Well S 3.6 feet. Pumping was at a constant 8 gpm.

RESEARCH STATION 78-110

Withams

This station is located 0.8 miles north of Withams in northern Accomack County. Four wells were drilled at this location with the following screen locations:

TABLE 11. GROUND WATER QUALITY OF RESEARCH STATION 77-108

WELL	A		B		C	
DEPTH (MSL, Ft)	-3		-133		-237	
Date	9/78	8/80	9/78	8/80	9/78	8/80
pH	7.6	5.7	8.0	7.6	8.3	7.8
Alk./Acid. (as $CaCO_3$)	12	11	108	101	217	132
Total Solids	108		180		327	233
Chloride	16	6	10	10	39	12
Hardness, EDTA (as $CaCO_3$)	47	54	110	96	40	112
Nitrogen (TKN)	0.1-	0.1	0.1	0.2	0.4	0.4
Total Phosphorus	0.1-	0.1-	0.1-	0.1	0.1-	0.1
Nitrate (as N)	0.04-	0.04-	1.32	0.04-	0.42	0.04-
Sulphate	37	42	9	1-	7	1-
Total Org. Carbon	1-	4	9	5	16	6
Fluoride	0.10-	0.01-	0.10-	0.1-	0.62	0.1-
Calcium	12	12	40	31	11	32
Iron	1.1	0.86	0.1-	0.14	0.1-	1.31
Magnesium	5	4.8	6	3.2	4	16
Manganese	0.05	0.05	0.02	0.06	0.01	0.03
Sodium	8	7	9	10	107	14
Potassium	1	1	3	1.4	7	8.1
Conductivity		179		248		307

All parameters in mg/l except pH and conductivity (micro-mhos/cm)

TABLE 12. GROUND WATER QUALITY OF RESEARCH STATION 77-109

WELL	S		A		B		C	
DEPTH (MSL, Ft)	-18		-118		-216		-278	
Date	6/78	8/80	6/78	8/80	6/78	8/80	6/78	8/80
pH	7.7	7.0	8.0	7.7	8.2	8.0	8.9	8.2
Alk./Acid. (as $CaCO_3$)	82	93	144	143	259	208	1397	683
Total Solids	158		226	215	453	269	48830	1667
Chloride	14	19	1	7	1	9	2	515
Hardness, EDTA (as $CaCO_3$)	81	96	124	125	39	42	58	70
Nitrogen (TKN)	0.1	0.2	0.6	0.7	1	1.6		3.8
Total Phosphorus	0.1	0.1-	0.1-	0.2	0.5	0.2		0.7
Nitrate (as N)		0.04-		0.04-		0.04-		0.04-
Sulphate	9	10.4	4	1-	4	1-	14	5
Total Org. Carbon	7	6	11	10	14	10	420	65
Fluoride	0.1-	0.1-	0.21		0.79		1.02	
Calcium	35	36		31	17	9	210	17
Iron	1.1	0.42		1.03	1.1	0.09	0.2	0.16
Magnesium	2	2		9.8	5	4.5	29	10.6
Manganese	0.04	0.04		0.03	0.01-	0.01-	0.06	0.01-
Sodium	14	13		10	166	79	580	555
Potassium	2	1.4		7.9	9	7.8	33	19
Conductivity	217	289	290	344	654	496	2198	2906

All parameters in mg/l except pH and conductivity (micro-mhos/cm)

Well	SWCB No.	Elevations (MSL, Ft)
S	100-426	-16 to -26
A	100-423	-110 to -120
B	100-424	-158 to -168
C	100-425	-220 to -230

The water levels have been recorded since October, 1978 and the data indicates an average increase of one foot in all the wells. Levels are similar in all four wells and range from 0.25 to +2.10 feet (MSL). Seasonal variations are minor and no tidal fluctuations were indicated from the data accumulated on a continuous recorder on Well B.

Water quality samples were obtained in 1979 and in 1980. The chloride value in Well C 126 mg/l (1979) is not correct, this value should be higher as is indicated by the total solids, sodium and conductivity values. (See Table 13).

During the sampling, pumping was constant and drawdowns were measured in Well A at 2.6, Well B at 12.8 and Well C at 20.3 feet.

RESEARCH STATION 79-111

Cheriton

This research station is located 0.5 miles west of the Town of Cheriton, Northampton County. At this site four wells were drilled with the following screen locations:

Well	SWCB No.	Elevation (MSL, Ft)
S	165-191	-45 to -55
A	165-188	-125 to -135
B	165-189	-255 to -265
C	165-190	-305 to -315

Water levels have been measured since July, 1979. These levels range from a high of +5.5 ft (MSL) in wells to a low of -4.0 feet (MSL) in Well C. Seasonal fluctuations range from 0 to 3 feet.

Quality samples were obtained in 1979 and in 1980. Well C is in the salt/fresh interface with chlorides of 385 mg/l (1979) and 640 mg/l (1980). (See Table 14).

Drawdown measurements during pumping ranged from a value of .5 feet in Well B to 55 feet in Well C. Well A had a good value of 5.5 feet of drawdown. Pumping was at 8 gpm.

TABLE 13. GROUND WATER QUALITY OF RESEARCH STATION 77-110

WELL	S		A		B		C	
DEPTH (MSL, Ft)	-26		-120		-168		-230	
Date	1/79	8/80	1/79	8/80	1/79	8/80	1/79	8/80
pH	6.4	5.8	8.0		8.2	8.1	8.0	7.9
Alk./Acid. (as $CaCO_3$)	13	11	209		380	378	588	411
Total Solids	117	79	262		551	559	3035	1757
Chloride	13	15	11		62	66	126	790
Hardness, EDTA (as $CaCO_3$)	16	20	70		34	30	368	158
Nitrogen (TKN)	0.3	0.1	0.6		0.6	0.5	2.4	1.6
Total Phosphorus	0.1-	0.1-	0.1-		0.3	0.3	0.1-	0.2
Nitrate (as N)	0.04-	1.73	0.04-		0.04-	0.04-	0.04-	0.04-
Sulphate	21	18	1		2	7	188	83
Total Org. Carbon	1-	1-	5		11	12	16	11
Fluoride	0.10-	0.1-	0.17		0.68	0.42	0.54	0.37
Calcium	2.97	5	11.3	16	5.91	9	101	36
Iron	2.41	2.17	0.88	0.38	0.33	0.03	2.83	0.32
Magnesium	2.00	2.20	7.44	7.2	3.91	3.8	55.9	26
Manganese	0.07	0.05	0.04	0.03	0.03	0.01-	0.08	0.01
Sodium	10.9	8	61.2	64	212	199	891	500
Potassium	1.55	1.2	9.02	8.5	7.39	7.0	29.3	18
Conductivity	198	144	415		878	1048	4791	3594

All parameters in mg/l except pH and conductivity (micro-mhos/cm)

TABLE 14. GROUND WATER QUALITY OF RESEARCH STATION 77-111

WELL	S		A		B		C	
DEPTH (MSL, Ft)	-55		-135		-265		-315	
Date	6/79	8/80	6/79	8/80	6/79	8/80	6/79	8/80
pH	7.9	8.0	8.1	7.7	8.1	7.7	8.2	7.8
Alk./Acid. (as $CaCO_3$)	95	94	143	140	136	141	184	226
Total Solids	142	140	256	207	430	183	663	1609
Chloride	13	15	8	8	28	9	385	640
Hardness, EDTA (as $CaCO_3$)	89	88	109	104	118	94	199	258
Nitrogen (TKN)	0.1	0.1-	0.3	0.4	0.6	0.5	1.6	2.3
Total Phosphorus	0.1	0.2	0.1-	0.1-	0.1-	0.1-	0.1-	0.2
Nitrate (as N)	0.04-	0.04-	0.04-	0.04-	0.04-	0.04-	0.03-	0.04-
Sulphate	1	1-	1	1-	1-	1-	13	18
Total Org. Carbon	2	9	7	8	2	9	4	11
Fluoride	0.10-	0.1-	0.18	0.19	0.21	0.25	0.33	0.41
Calcium	32	33	22	25	25	24	31	100
Iron	0.5	0.22	2.1	0.62	0.1	0.24	0.3	5.26
Magnesium	1.8	1.9	11	11.6	12	11.5	18	43
Manganese	0.02	0.02	0.04	0.03	0.01-	0.01	0.05	0.01
Sodium	24	11	25	11	28	8	210	350
Potassium	1.1	1.5	17	15.4	20	20	26	35
Conductivity	215	261	275	330	341	357	1630	2071

All parameters in mg/l except pH and conductivity (micro-mhos/cm)

RESEARCH STATION 79-112

Willis Wharf

This station is located in Willis Wharf and 1 mile southeast of the Town of Exmore. Four wells were drilled at this site with screens located at the following screen depths:

Well	SWCB No.	Elevation (MSL, Ft)
S	165-195	-7 to -17
A	165-192	-95 to -105
B	165-193	-170 to -180
C	165-194	-273 to -283

Water levels have been obtained since July, 1979 and range from a high of 21.1 feet (MSL) in Well S to a low of -2.2 feet (MSL) in Well B. The data collected on a continuous water level recorder on Well B is influenced by the tide and by pumpage from American Original. Well C has water levels which are higher than Well B and range from -1.4 feet to 4.0 feet (MSL). The levels in Well A fluctuate from sea level and 2.2 feet (MSL).

Water quality samples were taken in 1979 and in 1980. Well C is below the salt/fresh water interface as is indicated by chloride values higher than 1500 mg/l. (See Table 15).

Drawdown measurements in Well A was 28 feet and Well C 41.2 feet. Pumping was a 8 gpm.

RESEARCH STATION 80-113

Concord Wharf

This station was drilled 1.4 miles west of Wardtown, Northampton County. Three wells were drilled at this location with screens located at the following depths:

Well	SWCB No.	Elevation (MSL, Ft)
A	165-197	-88 to -98
B	165-198	-193 to -203
C	165-199	-258 to -268

Water levels in these wells are near, or slightly above sea level. Data has been obtained since February, 1980.

Water quality samples were obtained in February and November 1980. Both Wells B and C are below the interface as indicated by the very high chloride values shown in Table 16.

Drawdown values for Well B and C were very large (in excess of 180 feet), only Well A could be measured and was 1.5 feet, indicating that the lower aquifers would be poor producers as compared to the upper aquifer.

TABLE 15. GROUND WATER QUALITY OF RESEARCH STATION 77-112

WELL	S		A		B		C	
DEPTH (MSL, Ft)	-17		-105		-180		-283	
Date	7/79	8/80	7/79	8/80	7/79	8/80	7/79	8/80
pH	6.5	5.8	8.0	7.7	8.1	7.9	8.3	7.8
Alk./Acid. (as $CaCO_3$)	15	14	181	181	169	168	381	383
Total Solids	163	121	316	231	279	251	3111	3276
Chloride	23	18	11	12	35	35	1604	1510
Hardness, EDTA (as $CaCO_3$)	56	52	146	152	118	110	306	320
Nitrogen (TKN)	0.2	0.1-	1.8	2.0	1.5	1.4	5.8	5.1
Total Phosphorus	0.1-	0.1-	0.1	0.1	0.1	0.3	0.2	0.2
Nitrate (as N)	1.8	0.79	0.07	0.04-	0.04	0.04-	0.02-	0.03
Sulphate	39	35	3	1	2	1	5	6
Total Org. Carbon	4	4	8	11	5	6	12	8
Fluoride	0.1-	0.1-	0.1-	0.1-	0.11	0.13	0.52	0.48
Calcium	13	15	29	32	23	26	42	72
Iron	0.8	0.82	0.9	0.17	0.3	0.2	0.7	3.9
Magnesium	5.0	4.9	14	19	13	18.8	19	58
Manganese	0.04	0.05	0.01	0.03	0.01-	0.02	0.01-	0.08
Sodium	30	12	24	11	50	40	440	105
Potassium	1.5	1.6	18	20	14	14.1	29	41
Conductivity	224	205	394	443	474	497	5428	5698

All parameters in mg/l except pH and conductivity (micro-mhos cm)

TABLE 16. GROUND WATER QUALITY OF RESEARCH STATION 77-113

WELL	A		B		C	
DEPTH (MSL, Ft)	-98		-203		-268	
Date	2/80	8/80	2/80	8/80	2/80	8/80
pH	7.9	7.5	8.4	7.8	8.5	7.7
Alk./Acid. (as $CaCO_3$)	104	105	317	310	323	336
Total Solids	187	186	3011	3434	9088	6506
Chloride	26	27	2083	1480	6200	7400
Hardness, EDTA (as $CaCO_3$)	88	86	287	290	723	780
Nitrogen (TKN)	0.3	0.4	3.3	3.3	6.5	6.3
Total Phosphorus	0.5	0.4				
Nitrate (as N)	0.04-	0.04-	0.01	0.04-	0.03	0.00
Sulphate	2	1	34	33	98	87
Total Org. Carbon	11	6	8	11	8	16
Fluoride	0.11	0.13	0.53	0.54	0.45	0.44
Calcium	23	26	145	98	123	113
Iron	1	0.66	18.55	5.33	10.4	0.43
Magnesium	5.9	6.3	48.5	45.0	113	116
Manganese	0.07	0.08	0.23	0.11	133	0.03
Sodium	21	21	900	86	1933	1970
Potassium	5.9	6.2	36	35	60	61
Conductivity	304	347	3151	5286	7985	10722

All parameters in mg/l except pH and conductivity (micro-mhos/cm)

RESEARCH STATION 80-114

Perdue

This station is located one and a half miles north of the Town of Accomac, just west of Perdue's well field. Four wells were drilled at this site with screens located at the following screen depths:

Well	SWCB No.	Elevation (MSL, Ft)
S	100-442	15 to 5
A	100-443	-105 to -115
B	100-444	-175 to -185
C	100-445	-260 to -270

Water levels have been obtained since March, 1980 and range from 41.3 feet (MSL) in Well S to -41.75 feet (MSL) in Well C. The data collected by the continuous water level recorders on Wells B and C is influenced by pumpage from Perdue. The water level in Well A ranges from 3.14 to 10.11 feet (MSL). Well B has water levels which range from -20.67 to -6.4 feet (MSL).

Quality samples were obtained in February, 1980 and again in August, 1980. The salt/fresh water interface is deeper than Well C, which has a chloride value of 12 mg/l. (See Table 17).

RESEARCH STATION 81-115

Chincoteague

This station is located at the Town of Chincoteague well field, 4.2 miles west of the town. Five wells were drilled at this site with screens located at the following depths:

Well	SWCB No.	Elevation (MSL, Ft)
A	100-448	-19 to -39
B	100-449	-104 to -124
C	100-450	-189 to -209
D	100-451	-213 to -233
E	100-455	-234 to -254

Water levels have been obtained since March, 1981 and range from 3.88 feet (MSL) in Well A to -20.07 feet (MSL) in Well D. The data collected on continuous water level recorders on Wells C, D, and E reflect pumpage from the Town of Chincoteague's wells. Wells C and D have water levels which fluctuate from -8.30 to -21.5 feet (MSL). Well B has higher water levels which range from 2.03 to -.71 feet (MSL).

Water quality samples were taken in 1981. The salt/fresh water interface is close to the bottom of the screens of Wells D and E. (See Table 18).

TABLE 17. GROUND WATER QUALITY OF RESEARCH STATION 77-114

WELL	S		A	B	C	
DEPTH (MSL, Ft)	5		-115	-135	-270	
Date	2/80	8/80	2/80	2/80	2/80	8/80
pH	6.4	6.4	6.3	7.9	7.9	7.7
Alk./Acid. (as $CaCO_3$)	21	27	5	118	90	96
Total Solids	180	201	28	200	132	130
Chloride	16	21	4	14	12	10
Hardness, EDTA (as $CaCO_3$)	98	98	19	115	88	90
Nitrogen (TKN)	0.1-	0.1-	0.1	0.3	0.2	0.1
Total Phosphorus	0.1-	0.1-	0.1-	0.1-	0.1-	0.1-
Nitrate (as N)	9.69	0.22	0.01	0.02	0.03	0.74
Sulphate	38	45	6	2	2	1
Total Org. Carbon	4	5	8	6	6	4
Fluoride	0.1-	0.1-	0.1-	0.1-	0.1-	0.1-
Calcium	290	31	2	26	22	29
Iron	0.04	0.01	0.06	0.05	0.05	0.16
Magnesium	1.6	3.2	0.1	8.1	4.4	5.3
Manganese	13	0.04	0.01	0.02	0.01	0.03
Sodium	8	6	4	10	8	5
Potassium	0.5	8.4	1.2	5.8	1.9	2
Conductivity	254	344	38	264	214	264

All parameters in mg/l except pH and conductivity (micro-mhos/cm)

TABLE 18. GROUND WATER QUALITY OF RESEARCH STATION 77-115

WELL	A				B		
DEPTH (MSL, Ft)	-39				-124		
Date	3/81	5/81	8/81	5/82	3/81	5/81	5/82
pH	6.9	6.2	6.1	6.3	7.5	7.9	7.6
Alk./Acid. (as $CaCO_3$)	33	35	28	30	137	137	143
Total Solids	194	8667	698	143	275	212	205
Chloride	35	20	14	12	28	23	19
Hardness, EDTA (as $CaCO_3$)	66	180	62	59	98	86	100
Nitrogen (TKN)	0.1-	0.1	0.1	0.1-	0.1-	.1	0.2
Total Phosphorus	0.1-	0.1-	0.1	0.1	0.1	.2	0.1
Nitrate (as N)	1.5	1.0	2.4	2.8	.05-	.05-	.05-
Sulphate		34	38.4	33.6		3	1.0-
Total Org. Carbon		40	11	1-		11	13
Fluoride	0.1-	0.1-	0.1-	0.1-	0.1-	0.1-	0.16
Calcium	14.4	13.0	17.0	17.0	23.0	19.0	23.0
Iron	.5	3.5	42.0	.26	.4	.05	.15
Magnesium	6.2	7.0	6.8	-	9.5	7.2	-
Manganese	.43	.7	.68	.05	.06	.06	.07
Sodium	20.0	13.0	14.0	15.0	35.0	27.0	29.0
Potassium	3.1	2.8	3.8	1.8	9.5	7.9	9.0
Conductivity	309	212	213	212	468	350	387

TABLE 18 contd. GROUND WATER QUALITY OF RESEARCH STATION 77-115

WELL	C			D			E	
DEPTH (MSL, Ft)	-209			-233			-254	
Date	3/81	5/81	5/82	3/81	5/81	5/82	11/81	5/82
pH	7.8	7.7	7.6	7.8	7.9	8.0	8.1	7.9
Alk./Acid. (as $CaCO_3$)	183	192	185	215	231	219	178	181
Total Solids	365	339	334	554	702	486	465	496
Chloride	79	77	73	135	19	129	134	134
Hardness, EDTA (as $CaCO_3$)	186	173	164	128	68	64	217	230
Nitrogen (TKN)	1.0	1.2	1.4	1.0	1.0	1.8		0.7
Total Phosphorus	0.1-	0.1-	0.2	0.1	0.1	.2		0.1
Nitrate (as N)	.05-	.05-	.05-	.1	.05-	.05-		.05-
Sulphate		3	1.5		8	5.8	1.0-	4.9
Total Org. Carbon		5	7		18	8	4	6
Fluoride	0.1-	0.1-	0.11	.22	0.2	0.2		0.1-
Calcium	34	32	32	34	17	11		45
Iron	0.6	.5	1.7	1.2	3.5	.51		3.6
Magnesium	21	22.5		15	8.1	9.2		-
Manganese	.05	.05	.07	.05	0.1	.02		.05
Sodium	44	44	41	120	12.1	91		49
Potassium	22	22	20	22	15.4	17.0		31
Conductivity	784	597	689	1082	878	991	881	906

Appendix A

Kane Miller Corporation (KMC) Pump Test

A pump test was conducted in March, 1981 using the newest production well (165-158) in the KMC well field. Access was provided to four other wells, however, only the observation well (165-157) provided useable data for analyses. The other wells were affected by pumping prior to the pump test and were not fully recovered. Figure A-1 shows the location of the KMC wells and the research stations and Figure A-2 shows the cross section, lithology and screen locations of the KMC wells. A Theis plot was drawn for the observation well for the pumping period (Figure A-3) and semi-log plots were drawn on the recovery data for the production (Figure A-4) and observation well (Figure A-5). Values for transmissivity and the storage coefficient were as follows:

	Transmissivity		
	Pumping Period	Recovery Period	Storage Coefficient
Production well (165-158)	8928		
Observation well (165-157)	10150	10675	.00026

The distance drawdown graph (Figure 13 in main text) was drawn using a transmissivity of 10,000 gpd/ft and a storage coefficient of .0002. A continuous pumping period of four days was used to calculate the drawdown values. It should be noted that even though values as large as 1000 gpm are included in the graph these withdrawals would have to be spread out over a number of widely spaced wells, thus only the drawdowns for the larger distances will be representative.

The effects of the pumping disappear at 10,000 feet from the well for most pumping values. A research station (77-104) 7000 feet from the well field has been providing data for four years and although it is not possible to distinquish the effects of the pumping on the water levels at an individual year, a trend can readily be seen (Figure A-6) especially in the deeper zones. This declining trend is due to both the pumping at KMC and the lack of adequate rainfall during the last two years. Long term monitoring of water levels at this research station and the more recent station (79-111) west of Cheriton will provide more reliable data to evaluate the long term effects of the pumping stress in the area.

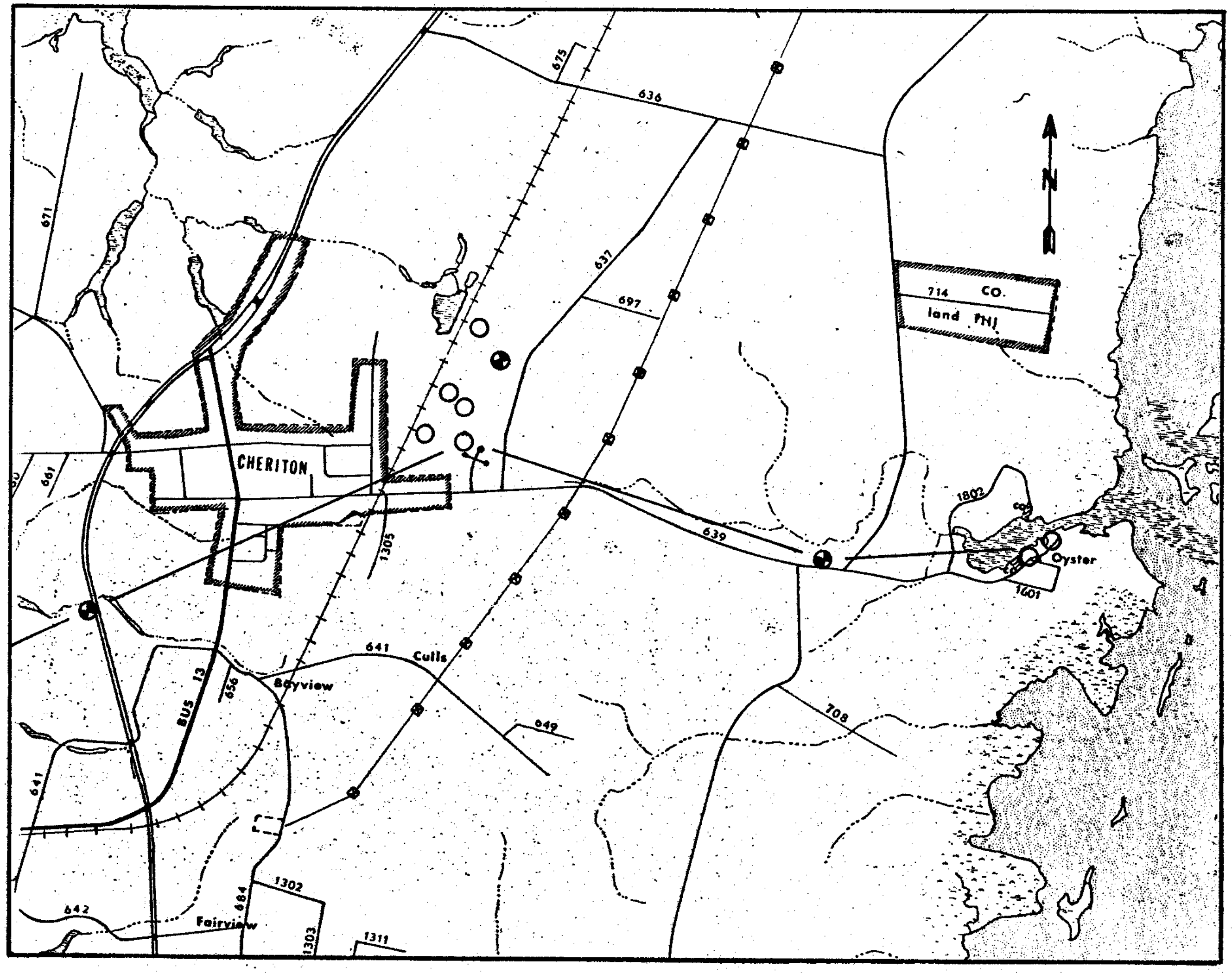


FIGURE A-1. LOCATION MAP OF THE CHERITON AREA

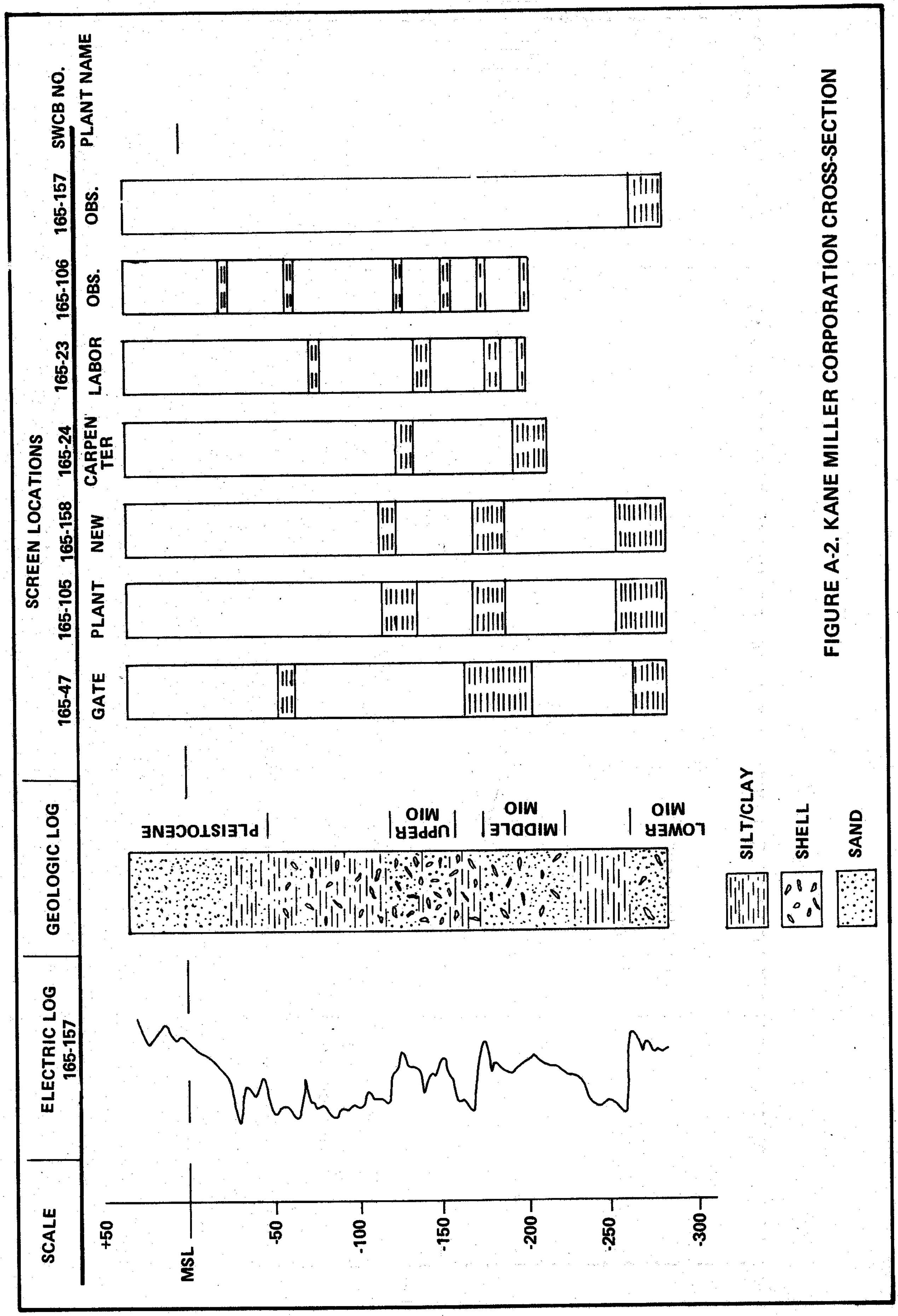


FIGURE A-2. KANE MILLER CORPORATION CROSS-SECTION

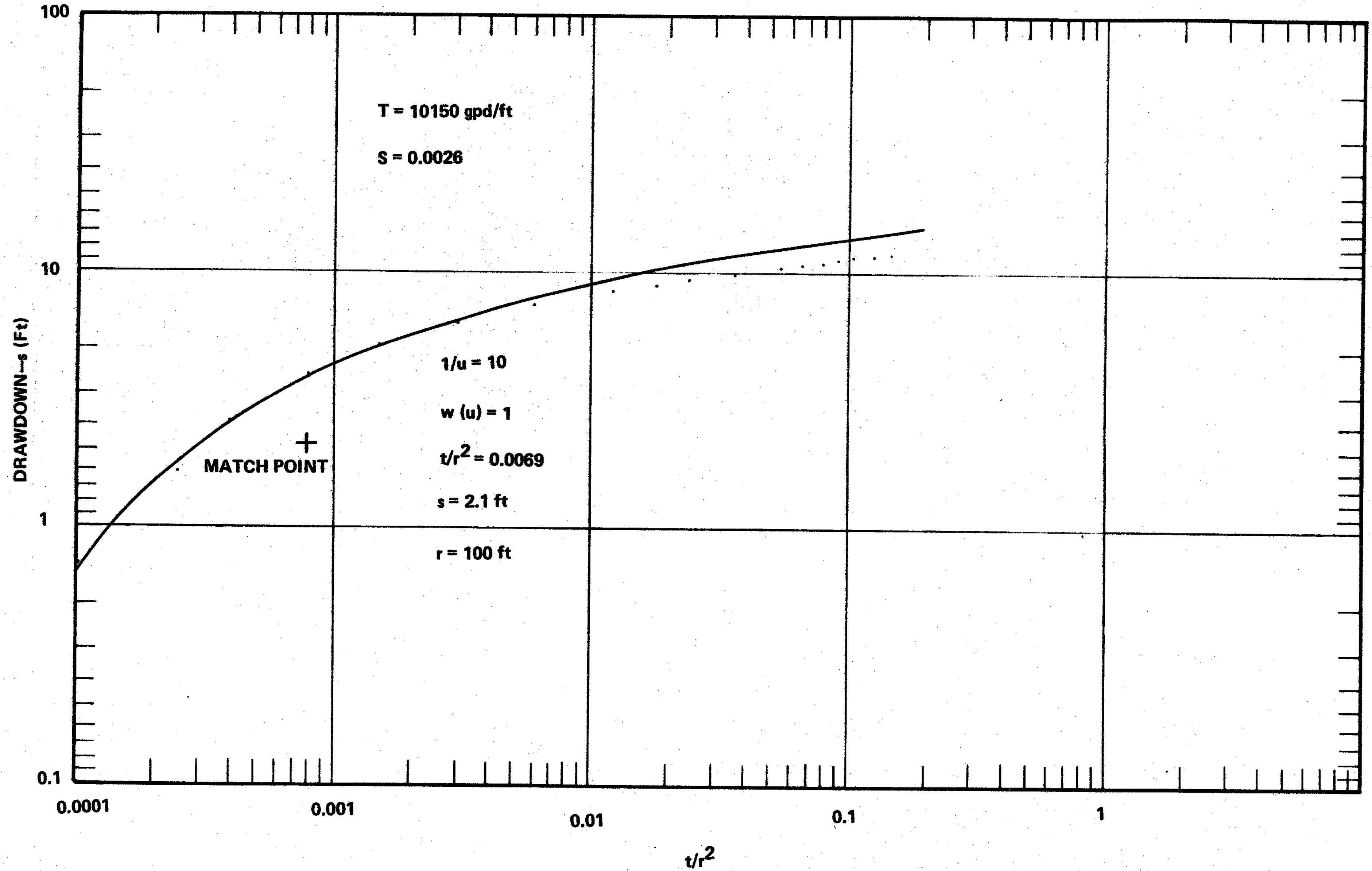


FIGURE A-3. TYPE CURVE SOLUTION FOR OBS. WELL 165-157

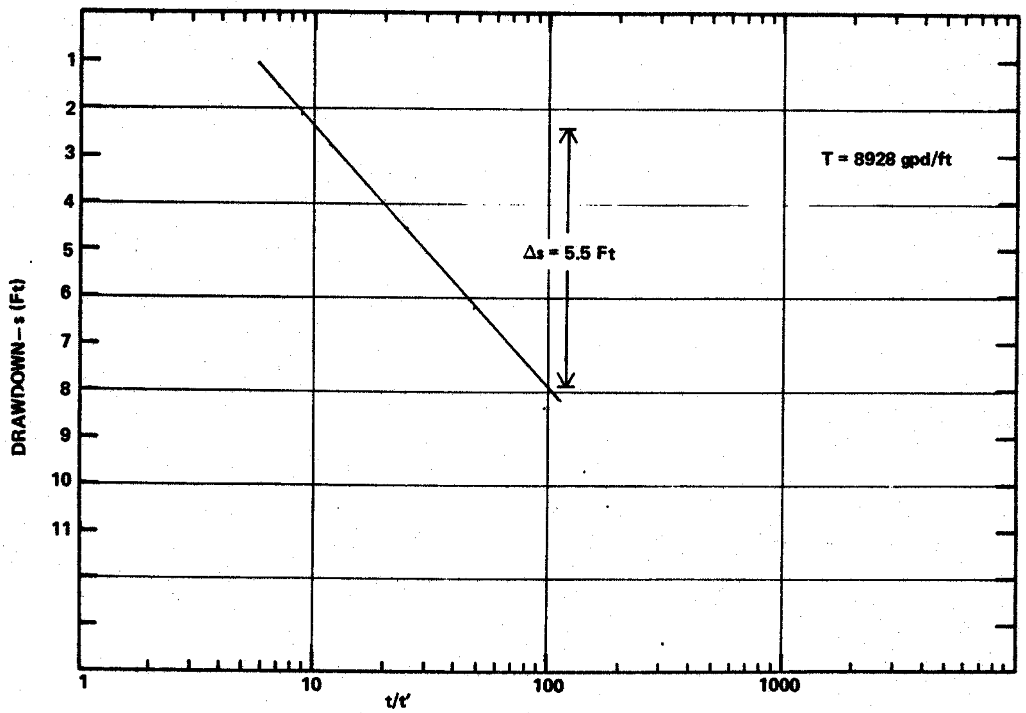


FIGURE A-4. RECOVERY SOLUTION FOR PROD. WELL 165-158

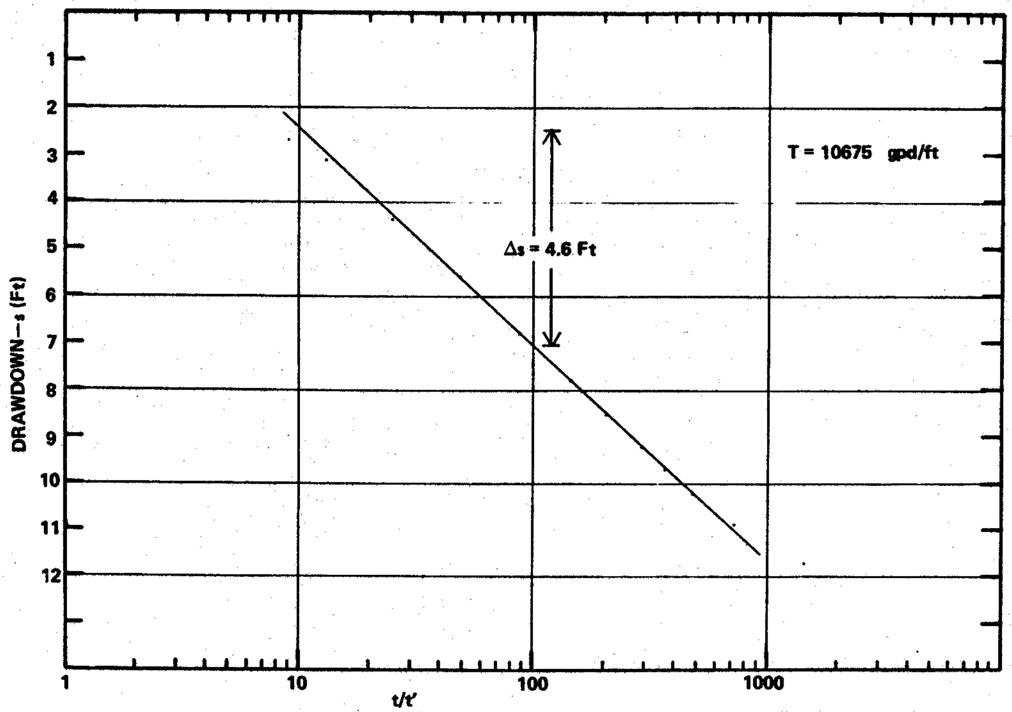
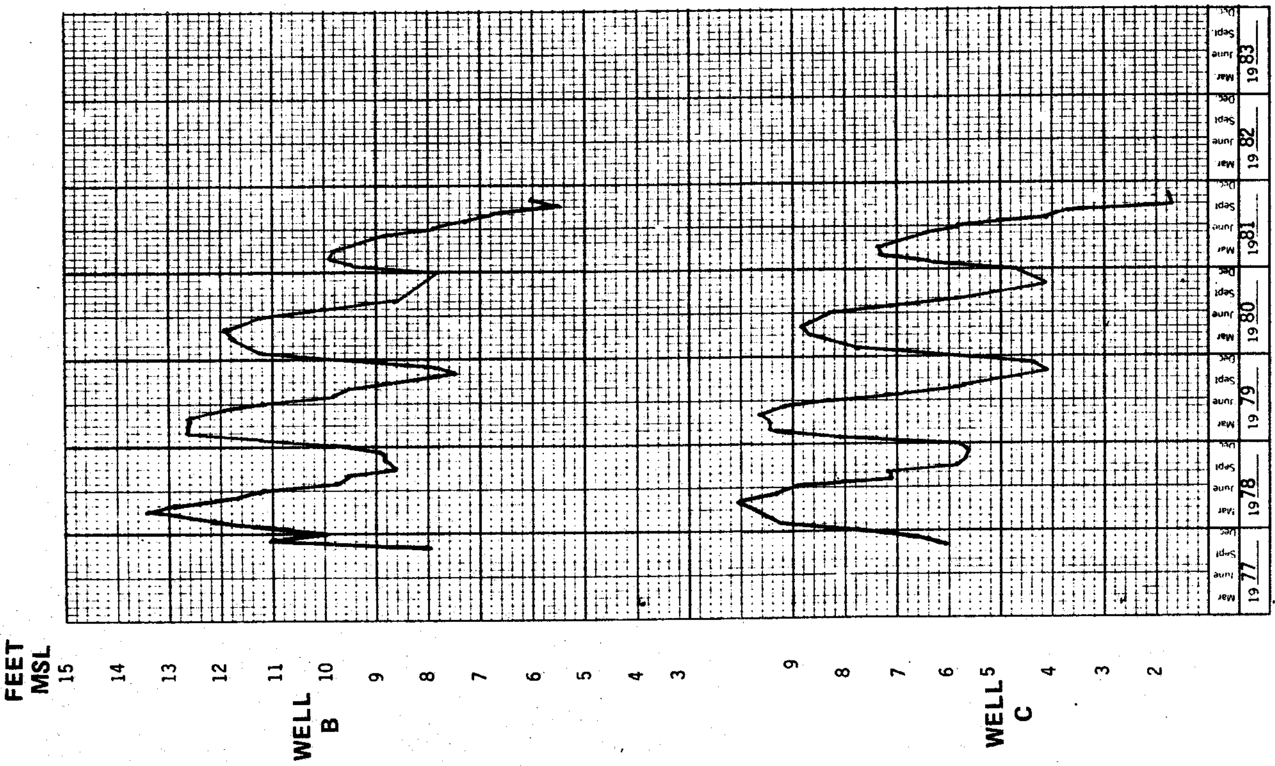


FIGURE A-5. RECOVERY SOLUTION FOR OBS. WELL 165-157



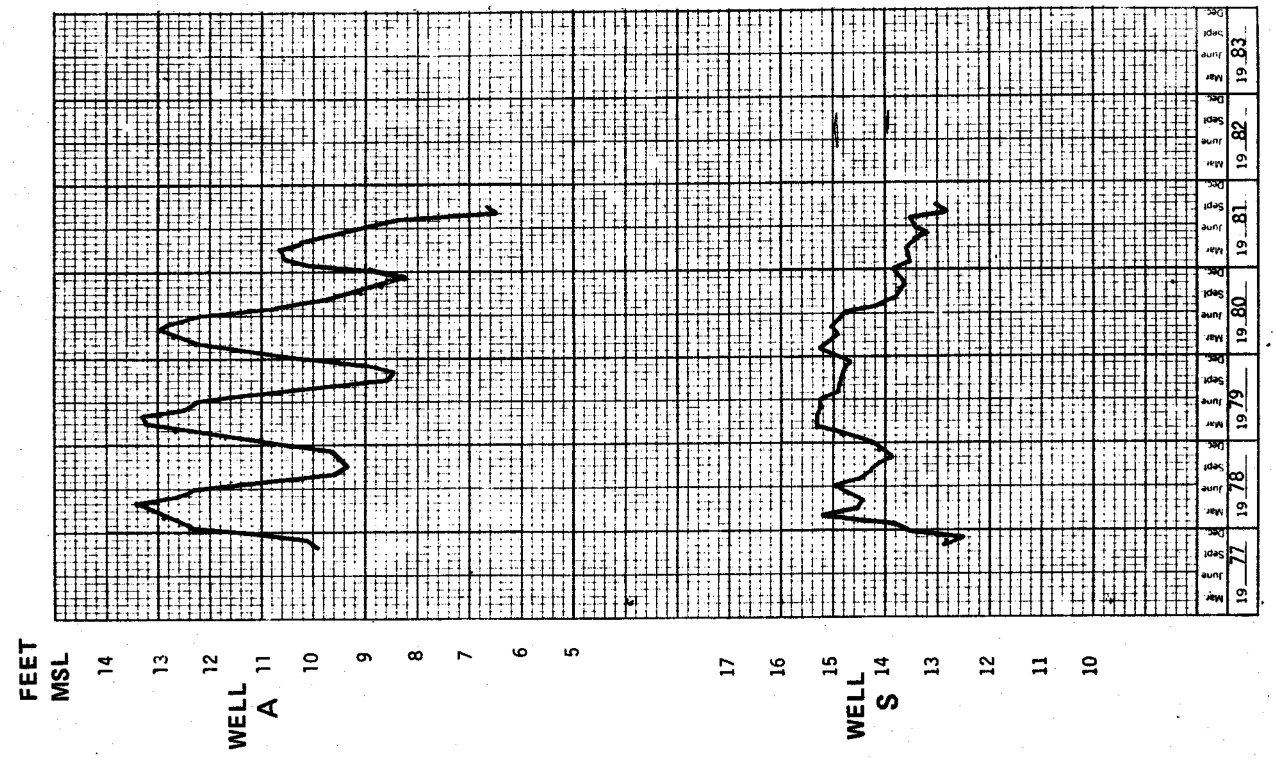


FIGURE A-6. WATER LEVEL READINGS AT RESEARCH-STATION 77-104

Appendix B

Exmore Foods Pump Test

A pump test was conducted in August, 1981 using the multi-screened production well 165-29 (plant well No. 8) and 3 observation wells. Note that well No. 165-33 (plant well No. 1) was in continuous use for refrigeration and could not be shut down. Drawdown at this well was stable at a pumping rate of 60 gpm. Figure B-1 shows the locations of the wells and Figure B-2 shows the lithology and screen locations. A Theis curve was drawn for the three observation wells (Figures B-3, B-4, and B-5) and Jacob plots were drawn using the recovery data of all four wells (Figures B-6-B-9). Values for transmissivity and the storage coefficient are tabulated below:

	Transmissivity Pumping Period	Transmissivity Recovery Period	Storage Coefficient
Production well (165-29)		20188	
Observation well (165-33)	19864		.00085
Observation well (165-34)	11684	21450	.00056
Observation well (165-39)	24830		.00089

The distance drawdown graph (Figure 18 in main text) was drawn using a transmissivity of 20000 gpd/ft and a storage coefficient of 0.0007. A continuous pumping period of four days was used to calculate the water levels of this graph.

Water levels were steady prior to the start of the pump test and as near to static as practically possible. Obstructions inside the casing were responsible for the loss of readings of the production well and an observation well (165-5), during the pumping period. Recovery readings were taken on the production well. As mentioned above well 165-33 was being pumped during the test, static water level was assumed to be the steady pumping level.

The calculated values for transmissivity exhibit a wide range, however it is felt that the high values obtained in observation well 165-39 are probably due to the time period of the pump test. Although the test was run for a 48 hour period, the distance to this well was too great for the water levels to reach steady state. As a result drawdown levels were less than expected and transmissivity values are artifically high. A shallow well (165-35) within the well field was monitored but no drop in water level, other than that due to the tidal cycle, was recorded. Problems with getting the measuring wire down the well were encountered in the production well (165-29) and no accurate record was obtained during the pumping period. Several measurements to 120 feet were taken during the first 20 minutes of the test, but nothing below this depth could be obtained. This well pumped at 260 gpm for the duration of the test. Recovery readings were taken after shutdown.

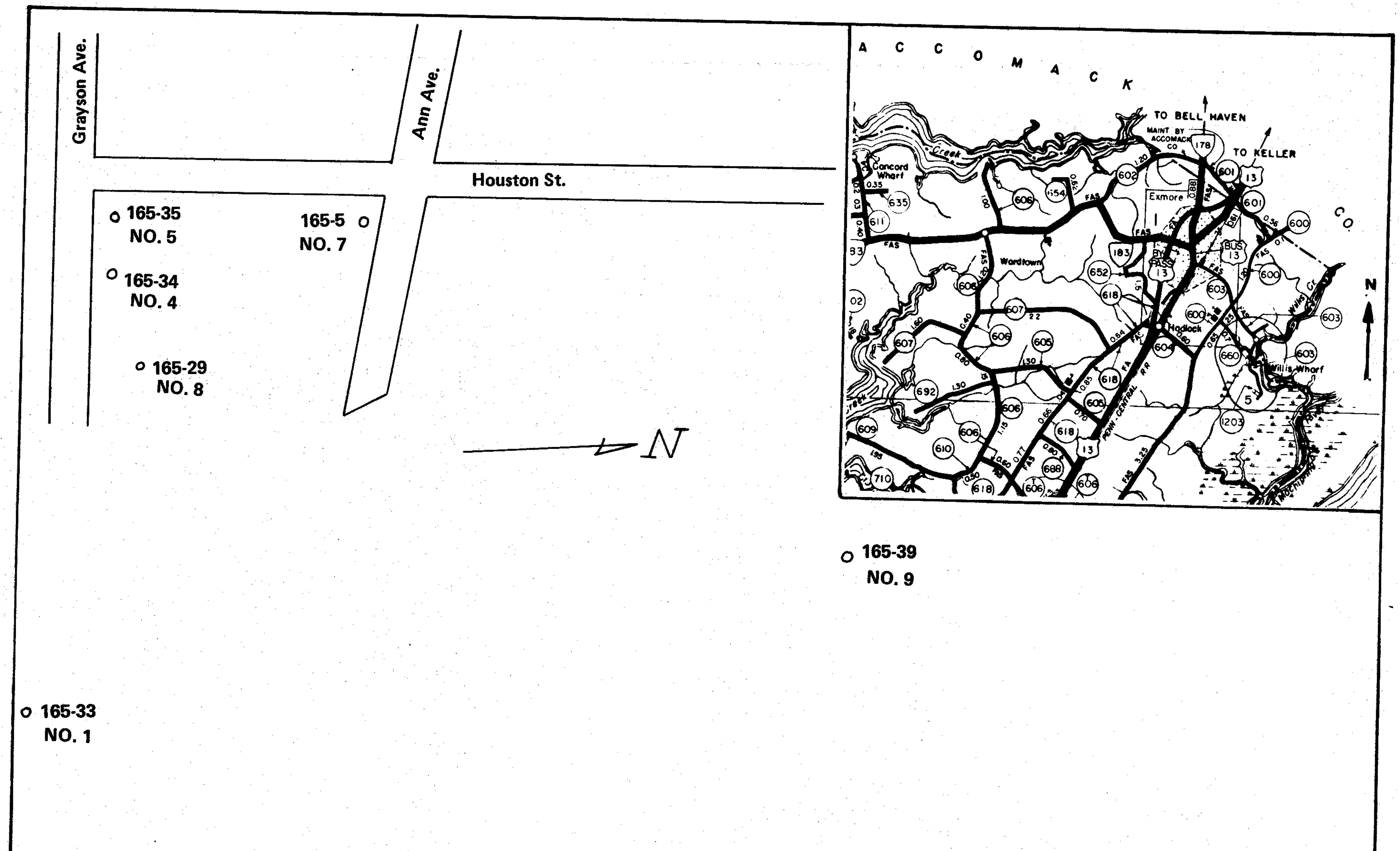


FIGURE B-1. LOCATION MAP FOR EXMORE FOODS WELL FIELD

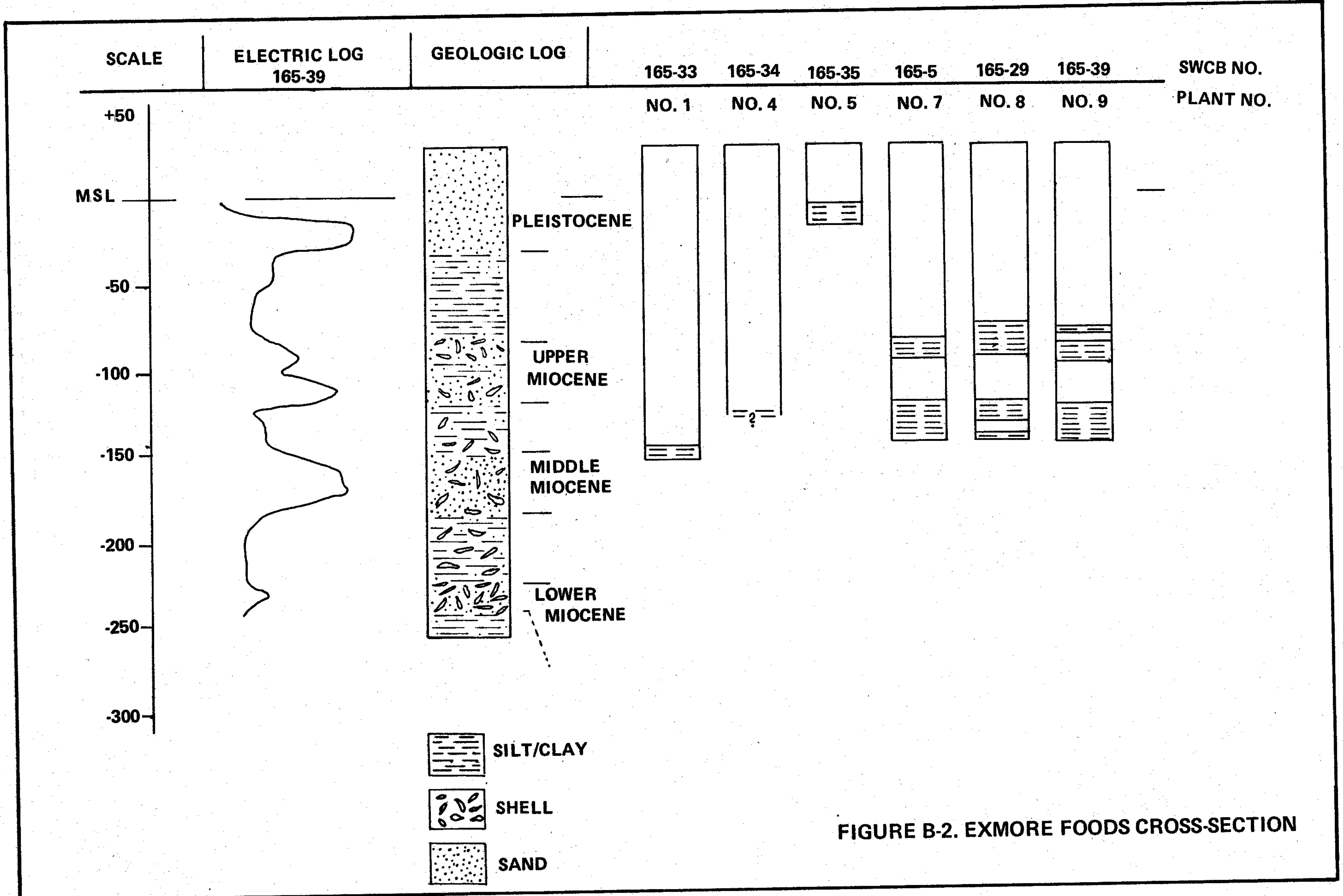


FIGURE B-2. EXMORE FOODS CROSS-SECTION

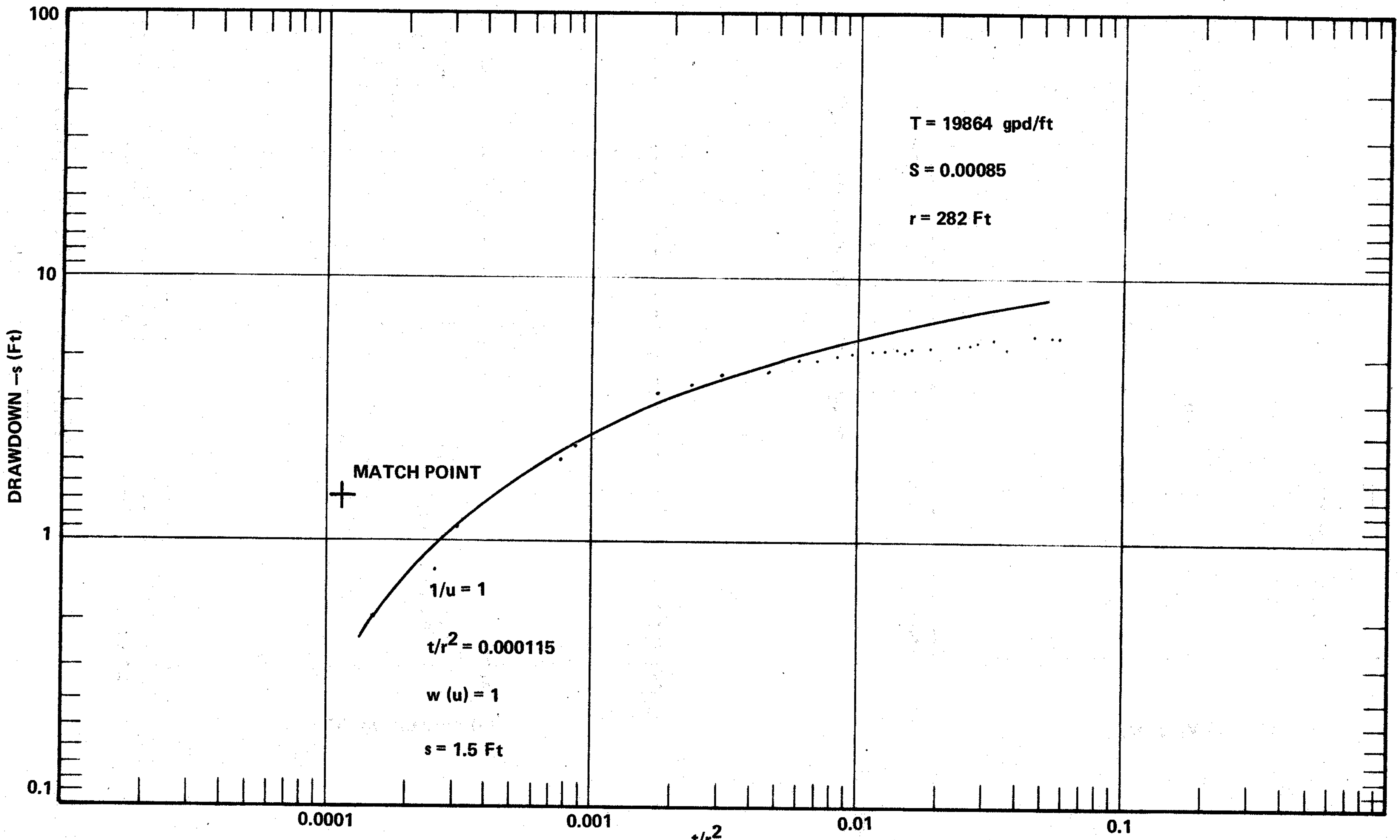


FIGURE B-3. TYPE CURVE SOLUTION FOR OBS. WELL 165-33

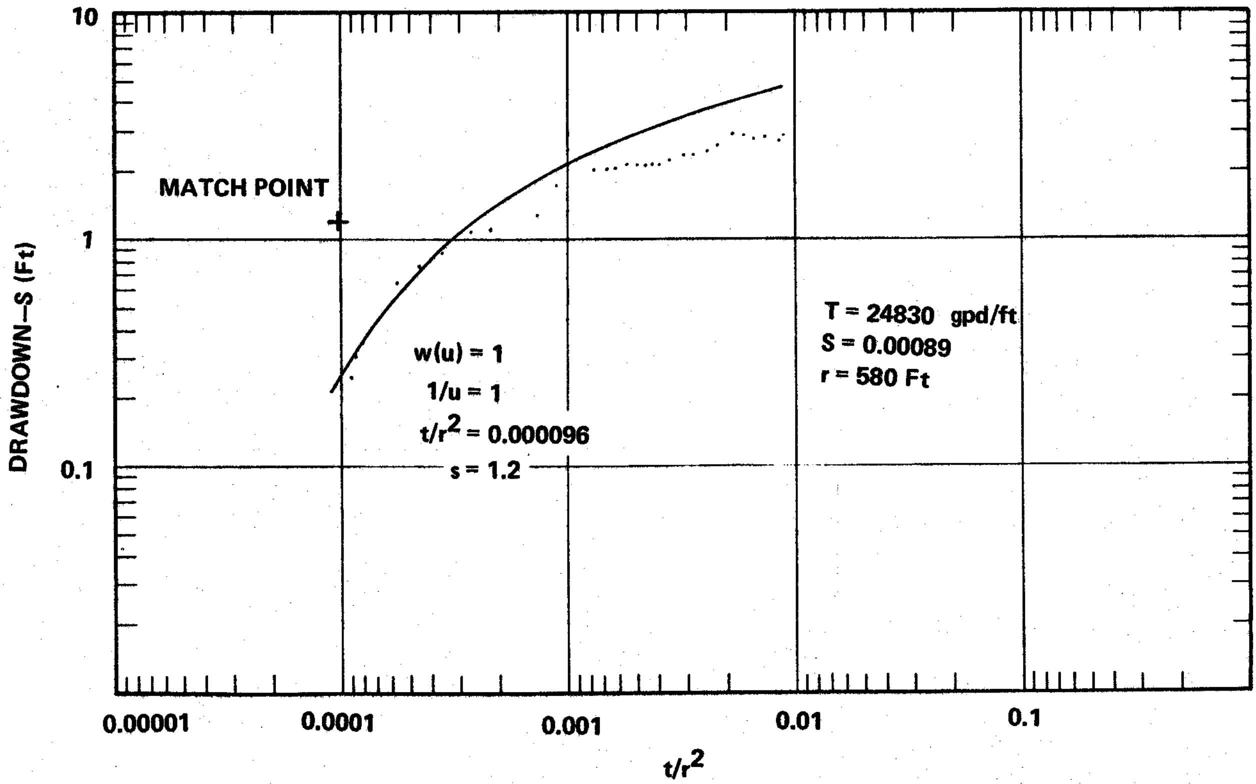


FIGURE B-4. TYPE CURVE SOLUTION FOR OBS. WELL 165-39

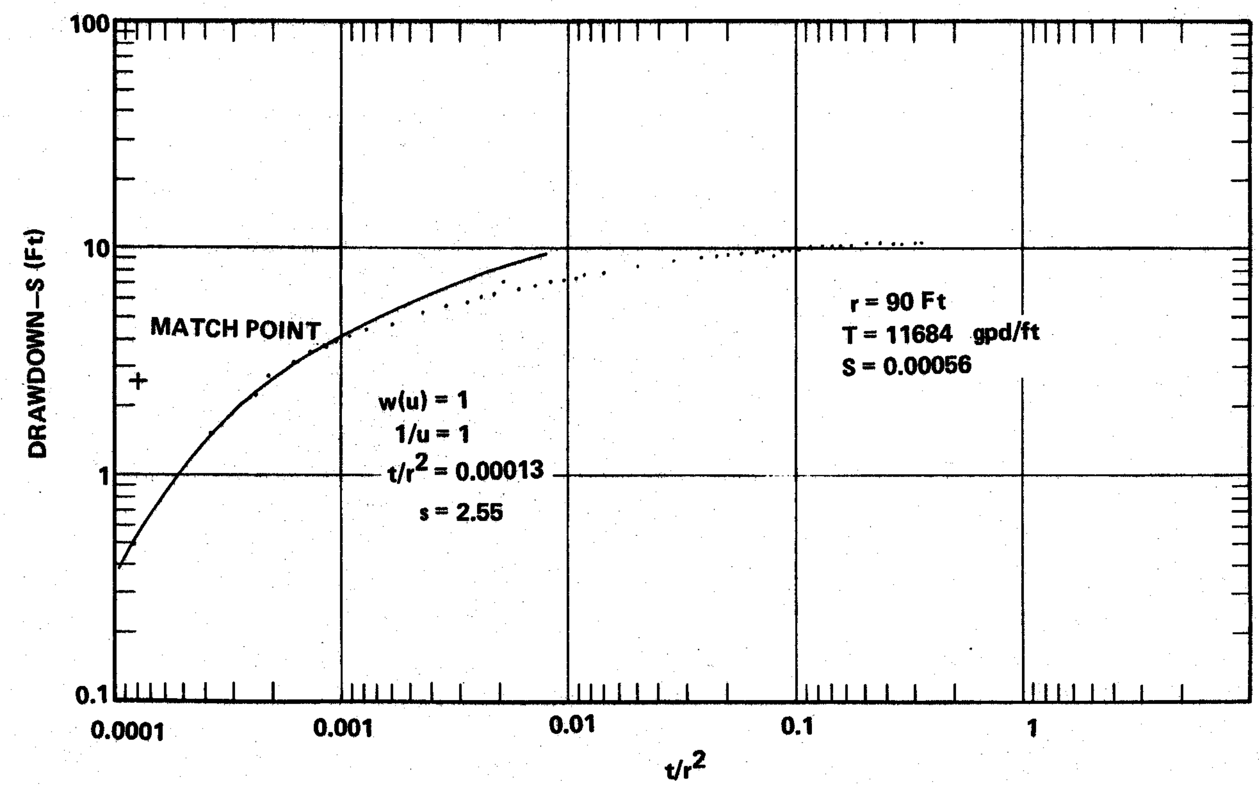


FIGURE B-5. TYPE CURVE SOLUTION FOR OBS. WELL 165-34

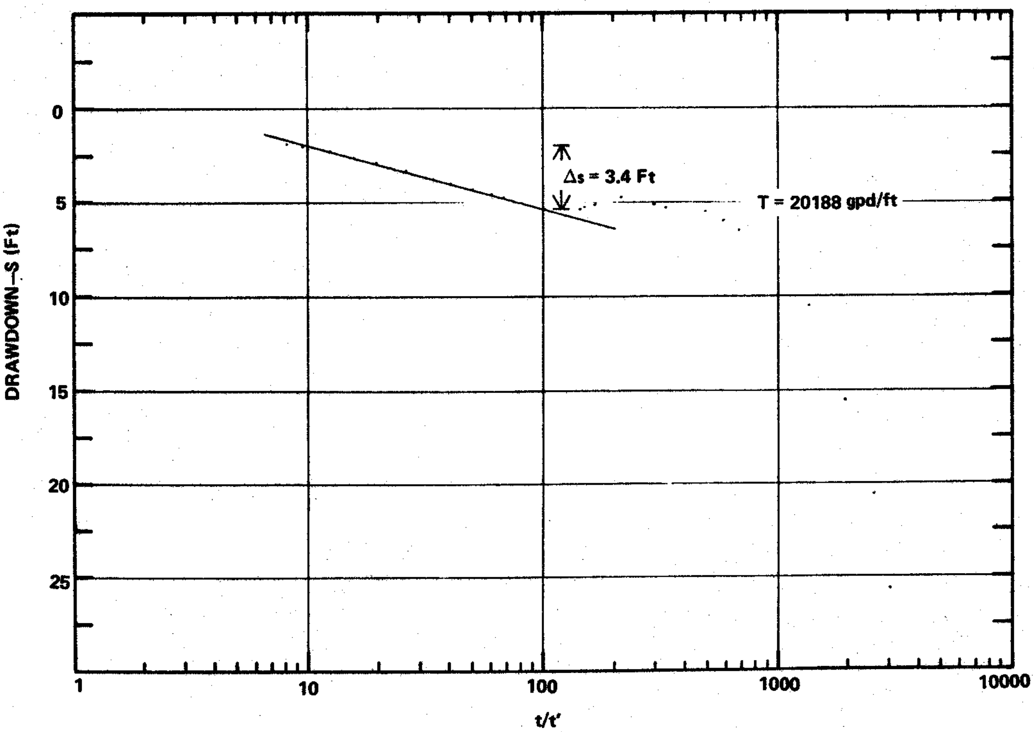


FIGURE B-6. RECOVERY SOLUTION FOR PROD. WELL 165-29

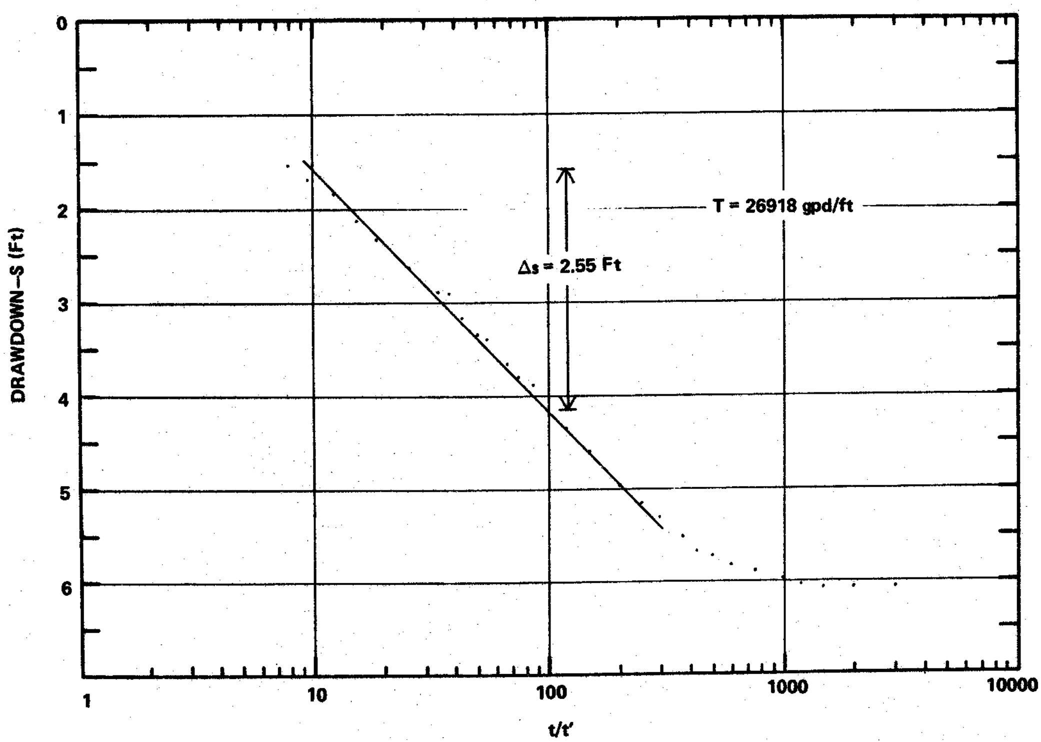


FIGURE B-7. RECOVERY SOLUTION FOR OBS. WELL 165-33

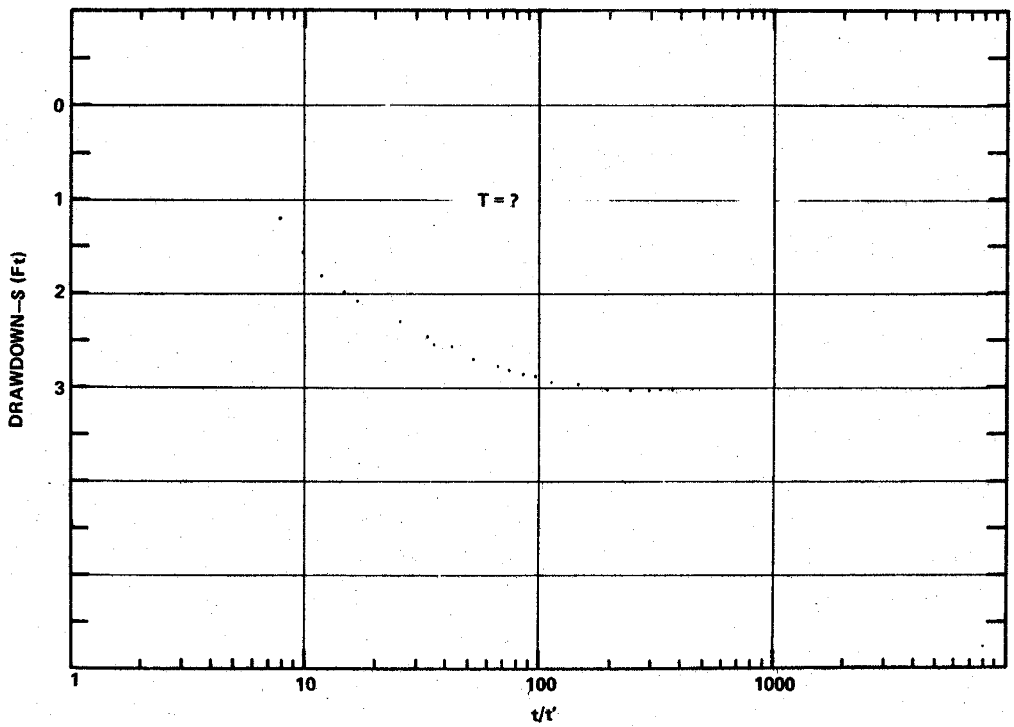


FIGURE B-8. RECOVERY SOLUTION FOR OBS. WELL 165-39

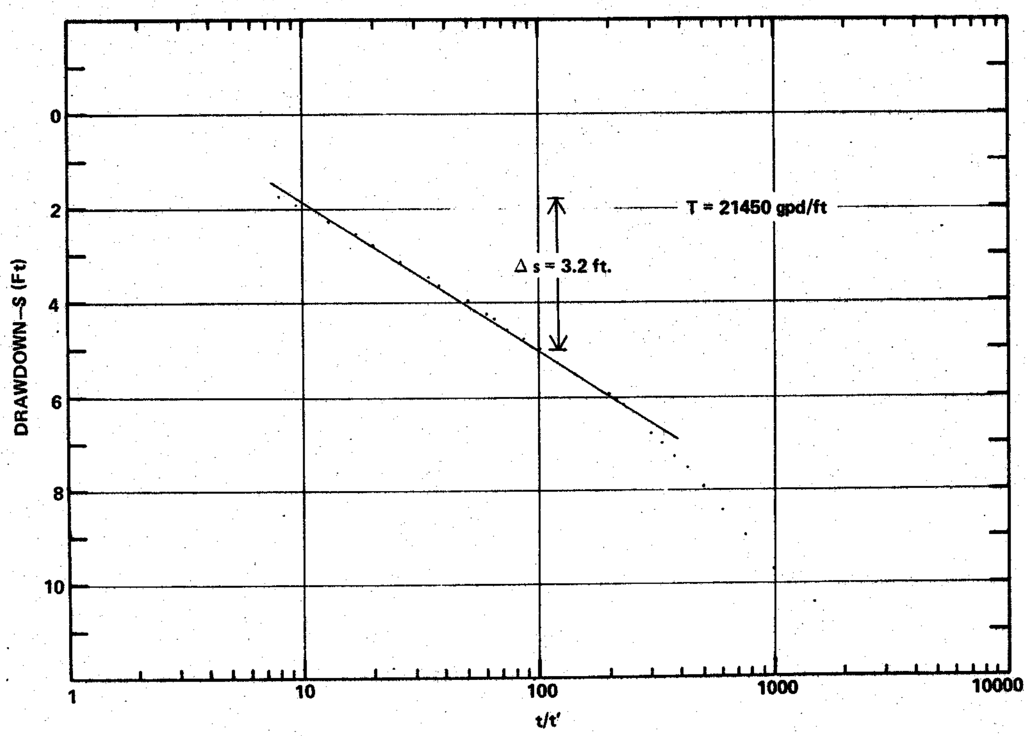


FIGURE B-9. RECOVERY SOLUTION FOR OBS. WELL 165-34

APPENDIX C

Town of Chincoteague Pump Test

A pump test was conducted in April, 1981 using the Town of Chincoteague well field. Production well 100-28 (town well No. 4) pumped at a rate of 280 gpm and two other town wells were used as observation wells. A research station was drilled by the SWCB to provide additional data and observation wells. Figure C-1 shows the location of the Town of Chincoteague well field and the research station. Figure C-2 shows the lithology and screen locations of the wells. Theis log-log curves were drawn for the pumping period of four wells (Figures C-3-C-6) and Jacob semi-log plots were drawn for the recovery period of five wells (Figures C-7-C-11). The resulting transmissivities and storage coefficeints are tabulated below.

	Transmissivity		
	Pumping Period	Recovery Period	Storage Coefficient
Production well (100-28		early 7274 late 10560	
Observation well (100-320)	22920	15562	0.000071
Observation well (100-452)	19447	18480	0.000098
Observation well (100-450)	8672	12118	0.000095
Observation well (100-451)	8228	8213	0.00048

Two of the observation wells (100-320 and 100-452) are multi-screened and since the upper screens are open to a layer which was minimally affected by the pump test, higher transmissivity values resulted. Both shallow and an intermediate zone well (wells 100-448 and 449) were also monitored but showed no drop in water levels due to pumping.

A distance-drawdown graph was drawn (Figure 25) using a transmissivity of 8,400 gpd/ft and a storage coefficient of 0.0002, with a continuous pumping period of four days. The larger pumping values can only be attained using several wells spaced some distance apart and thus only the greater distances should be used to evaluate the drawdowns at these pumping values.

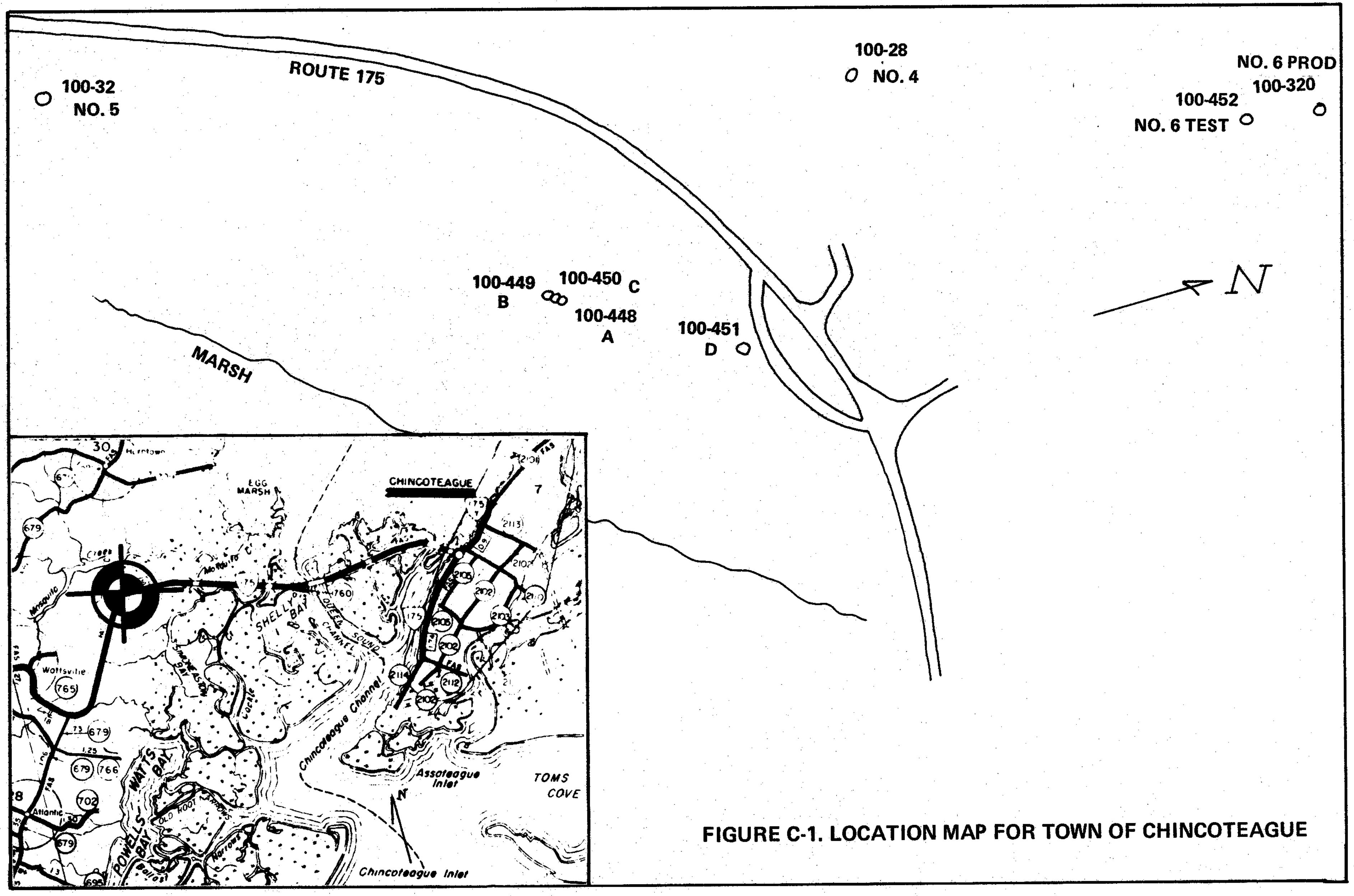


FIGURE C-1. LOCATION MAP FOR TOWN OF CHINCOTEAGUE

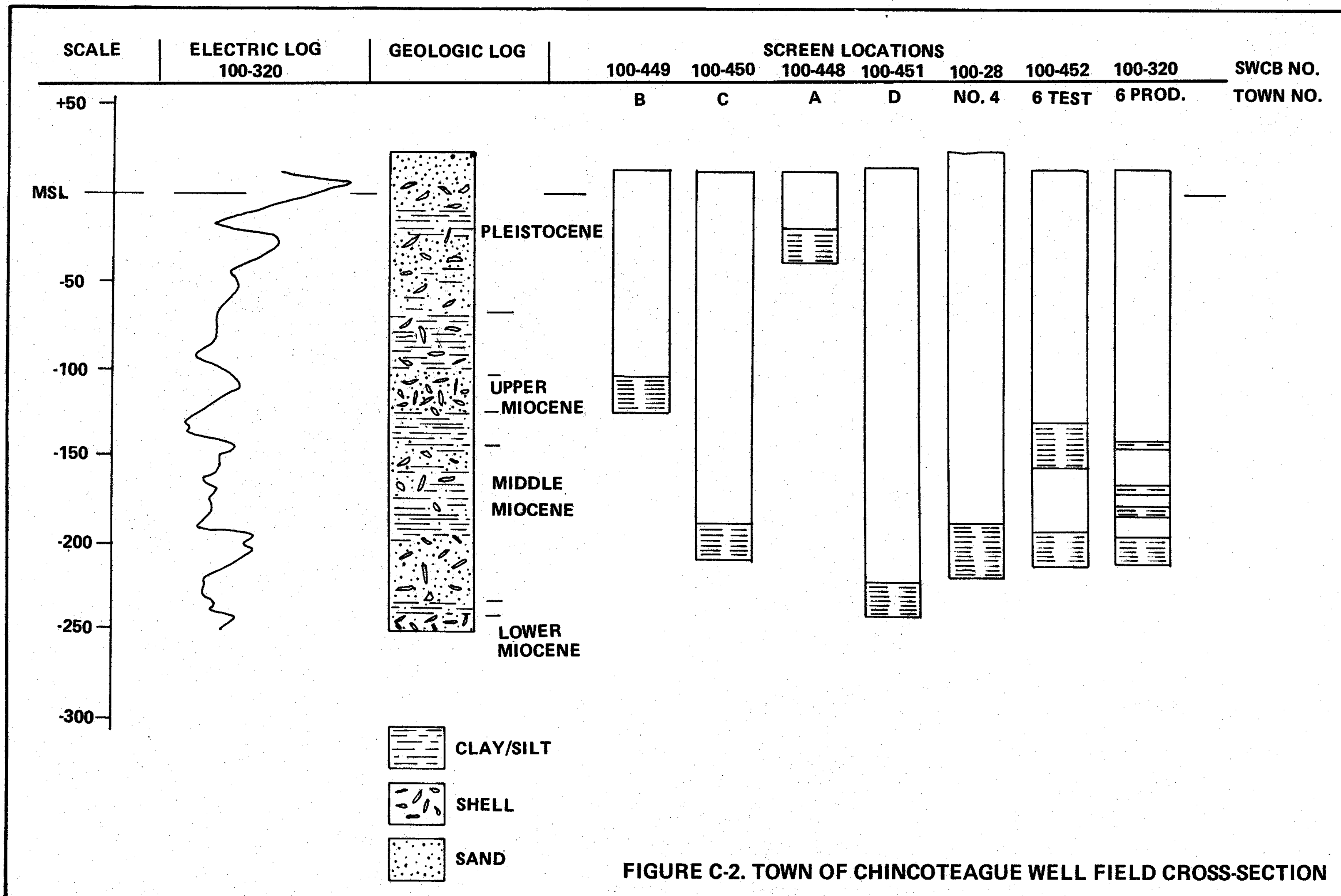


FIGURE C-2. TOWN OF CHINCOTEAGUE WELL FIELD CROSS-SECTION

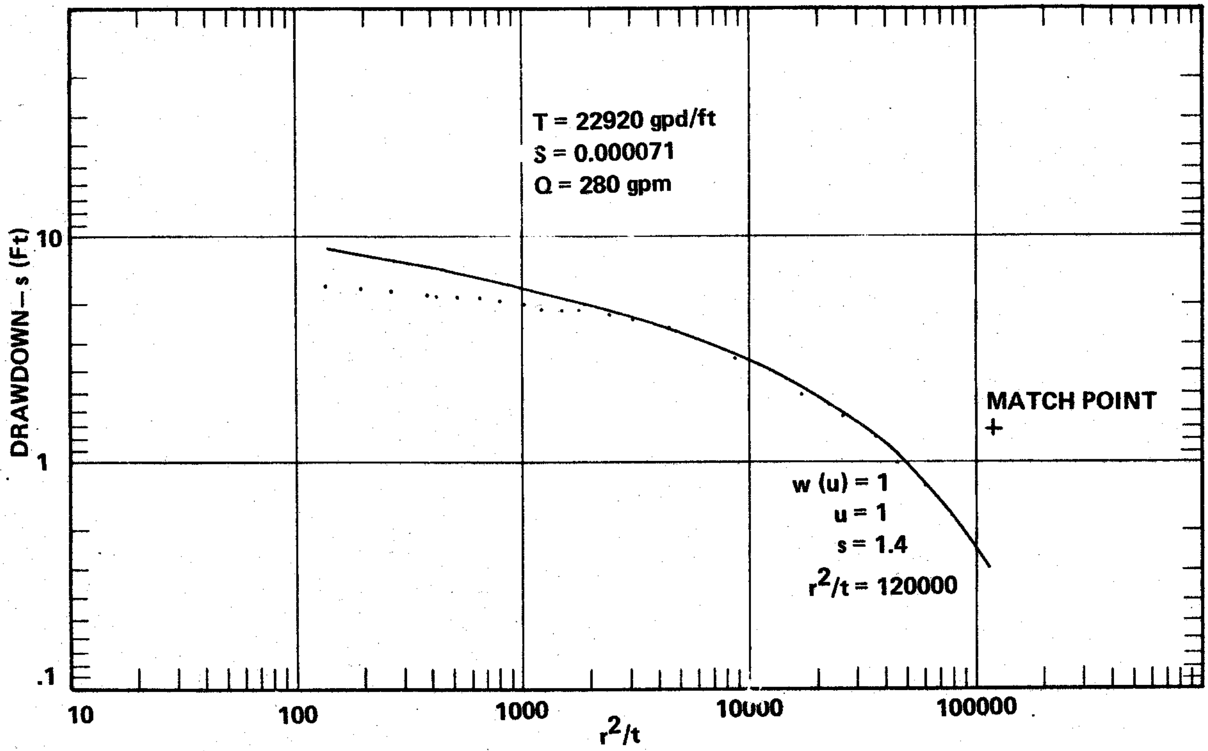


FIGURE C-3. TYPE CURVE SOLUTION FOR OBS. WELL 100-320

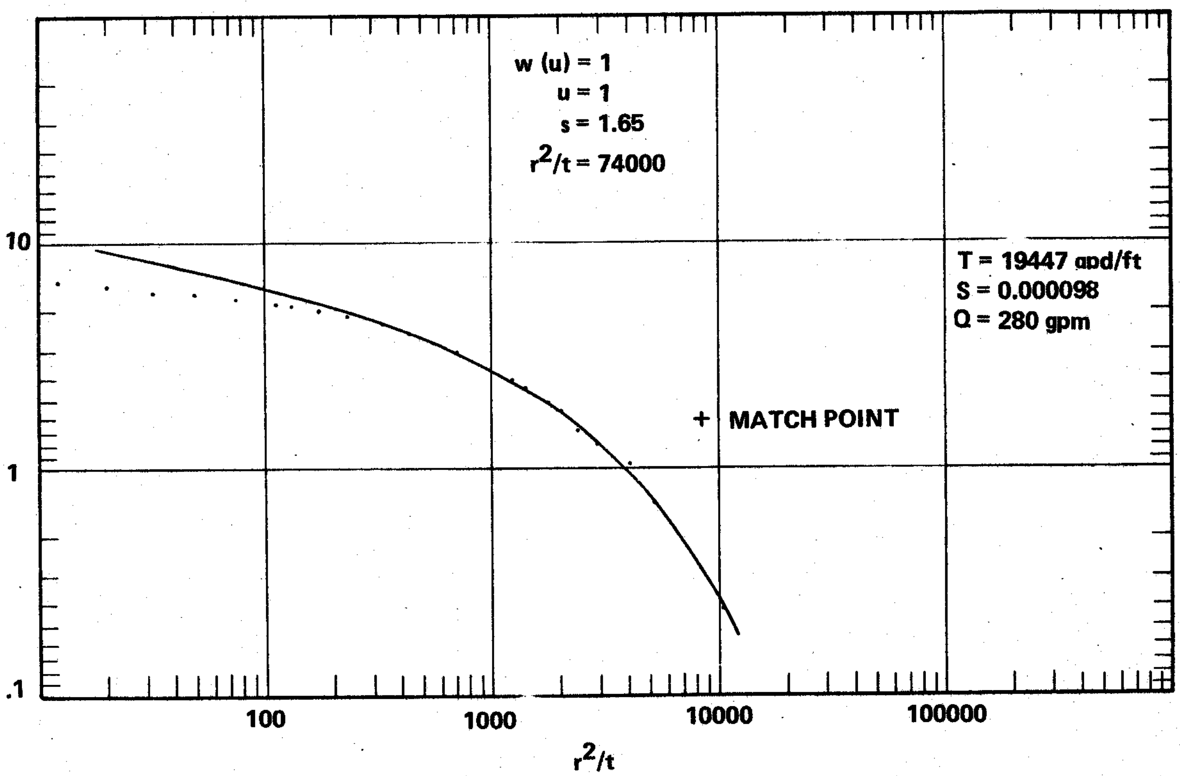


FIGURE C-4. TYPE CURVE SOLUTION FOR OBS. WELL 100-452

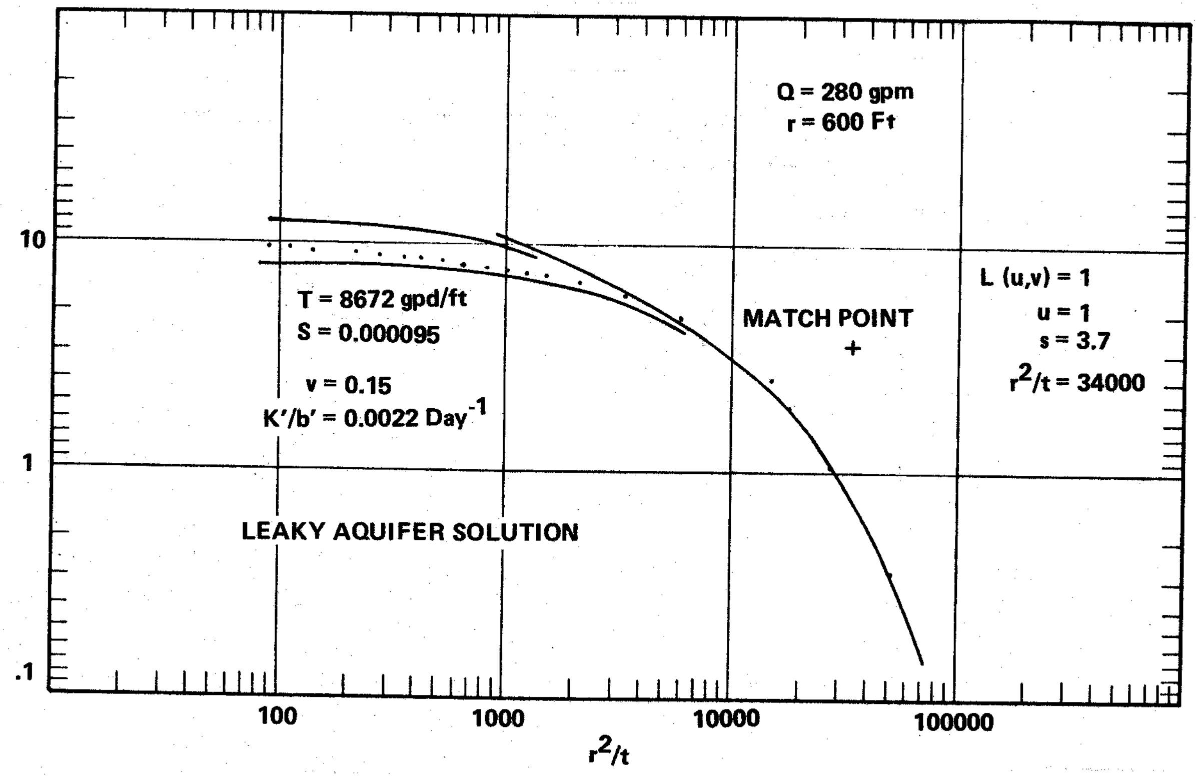


FIGURE C-5. TYPE CURVE SOLUTION FOR OBS. WELL 100-450

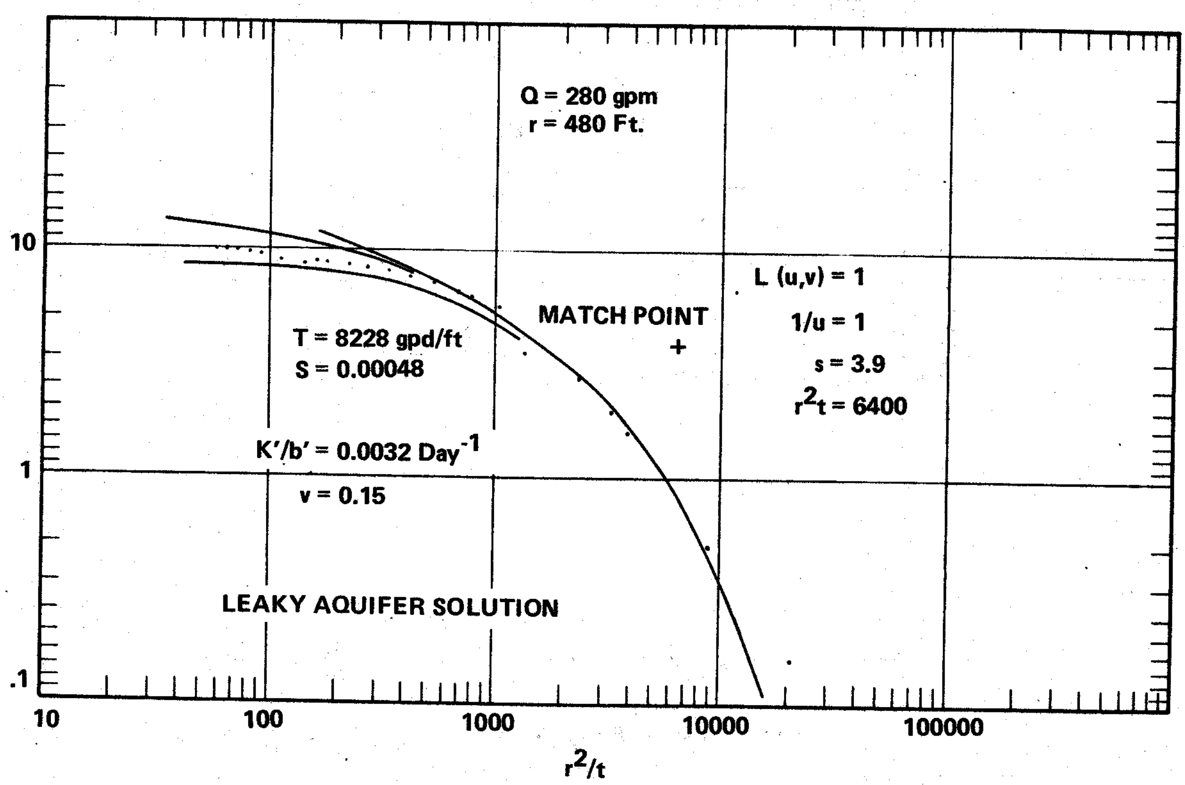


FIGURE C-6. TYPE CURVE SOLUTION FOR OBS. WELL 100-451

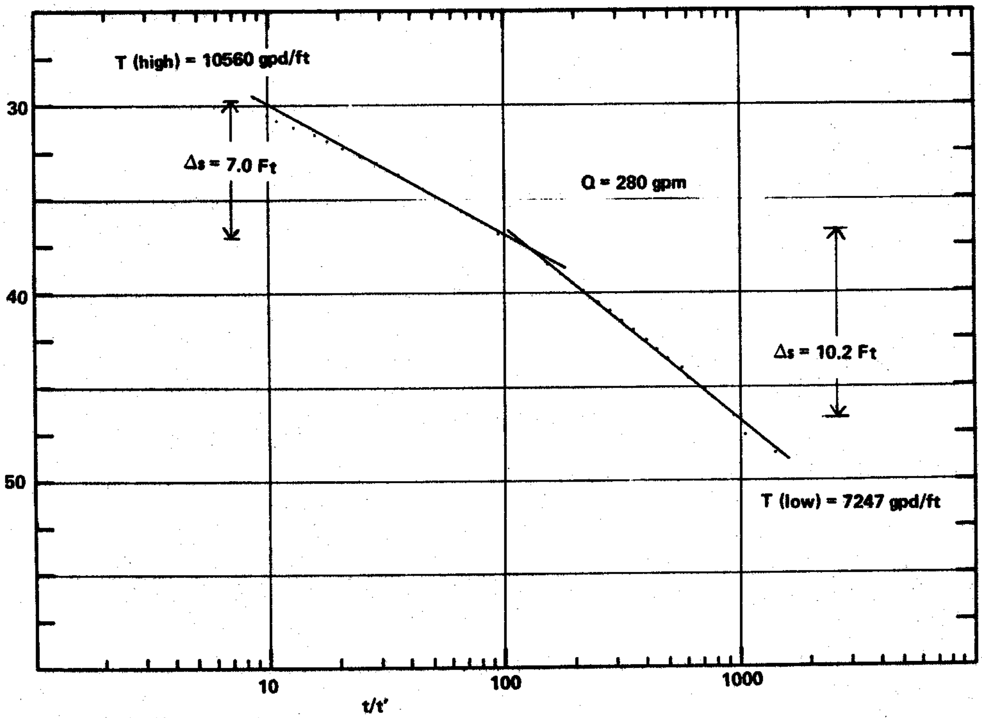


FIGURE C-7. RECOVERY SOLUTION FOR PROD. WELL 100-28

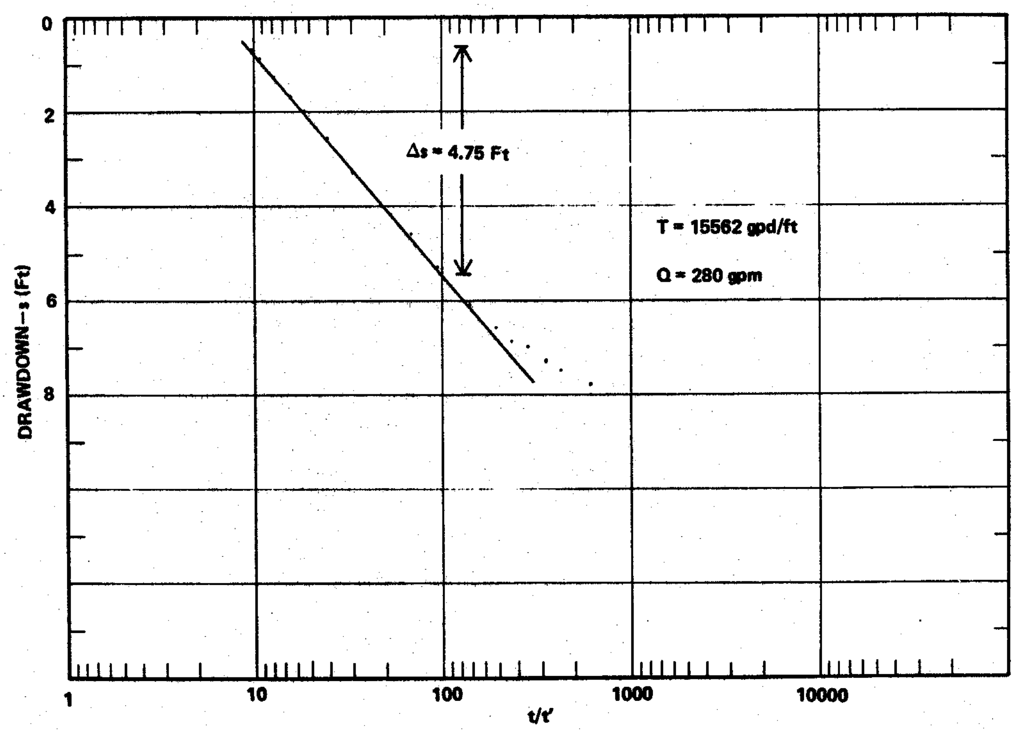


FIGURE C-8. RECOVERY SOLUTION FOR OBS. WELL 100-320

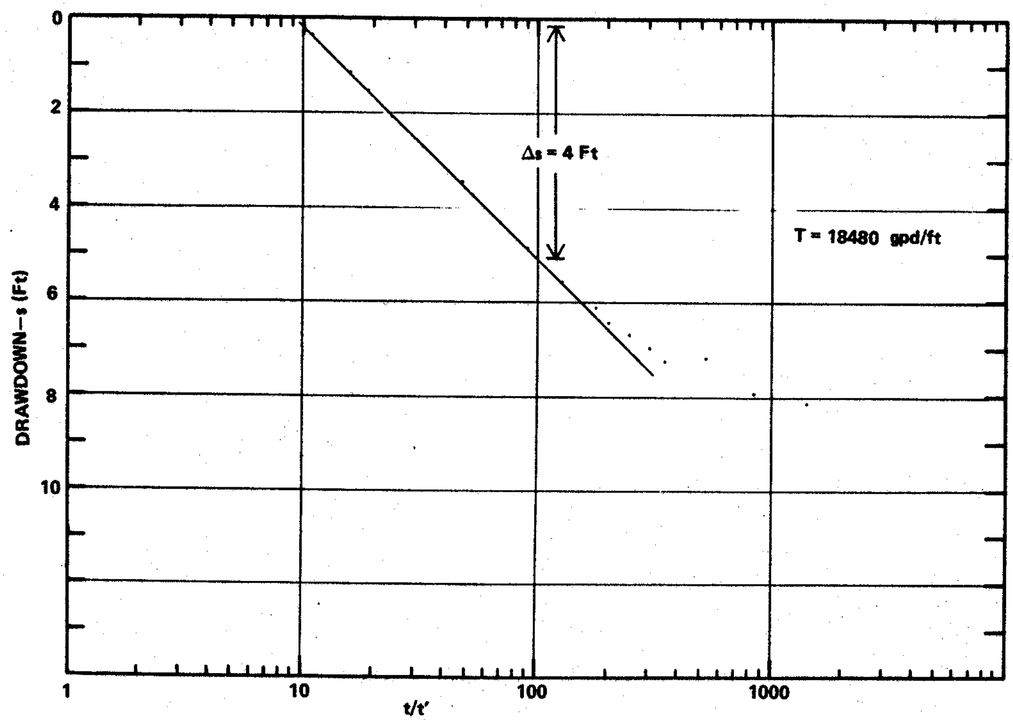


FIGURE C-9. RECOVERY SOLUTION FOR OBS. WELL 100-452

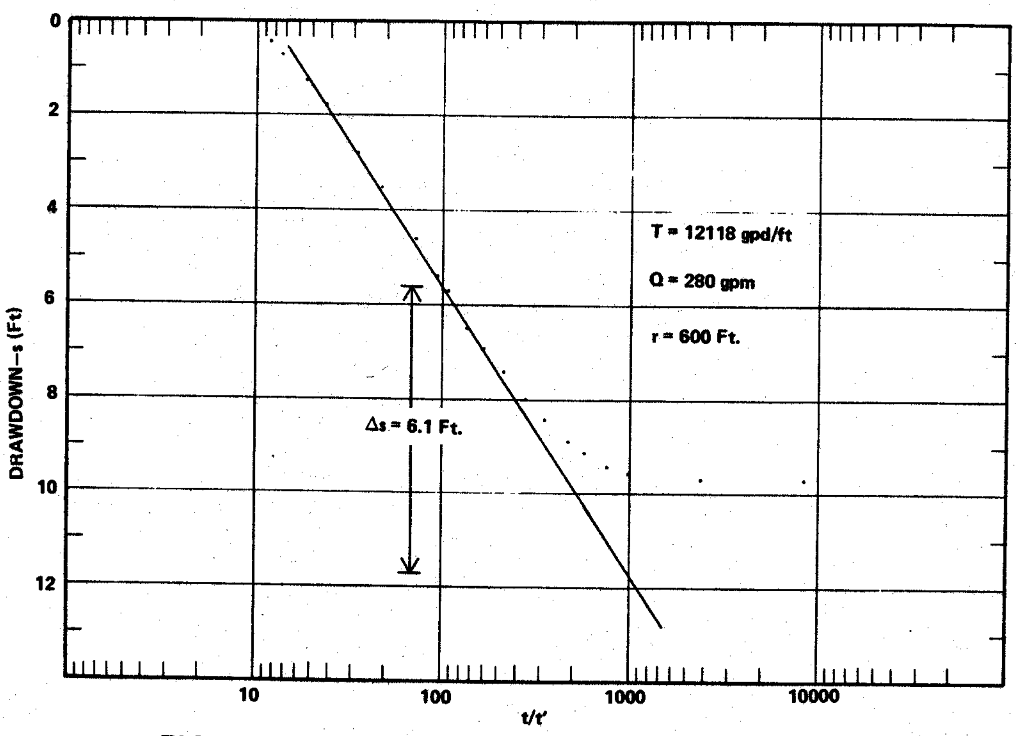


FIGURE C-10. RECOVERY SOLUTION FOR OBS. WELL 100-450

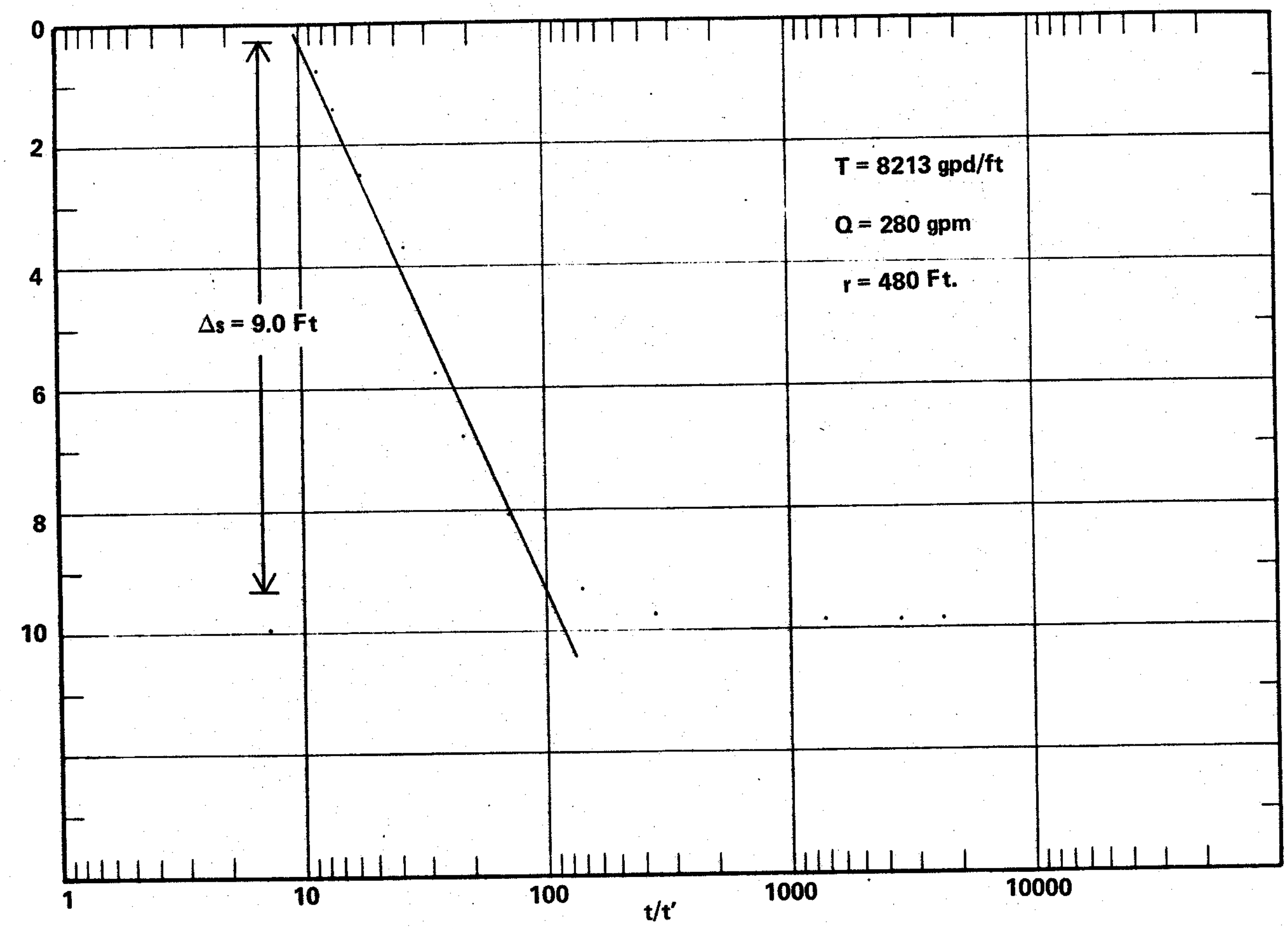


FIGURE C-11. RECOVERY SOLUTION FOR OBS. WELL 100-451